Situation Analysis
of Agro-Industrial Biogas Plants
in Bangladesh

JOINT STUDY OF THE

BANGLADESH BIOGAS DEVELOPMENT FOUNDATION

AND THE

GERMAN SOCIETY FOR SUSTAINABLE BIOGAS AN BIOENERGY UTILISATION

DECEMBER 2015 TO JULY 2016

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ABBREVIATIONS

ADB	Asian Development Bank
AIBP	Agro-Industrial-Biogas plants
ATEX	ATmosphere EXplosible
BARD	Bangladesh Academy for Rural Development
BAU	Bangladesh Agricultural University
BBDF	Bangladesh Biogas Development Foundation
BBS	Bangladesh Bureau of Statistics
BCC	Banker-Charnes-Cooper
BCSIR	Bangladesh Council of Scientific and Industrial Research
BDT	Bangladesh Taka
BEF	Bangladesh Employers' Federation
BERC	Bangladesh Energy Regulatory Commission
BIFFL	Bangladesh Infrastructure Finance Fund Limited
BMZ	Deutsches Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung
BRAC	Bangladesh Rural Advancement Committee - Building Resources Across Communities
BREB	Bangladesh Rural Electrification Board
BSCIC	Bangladesh Small and Cottage Industries Corporation
BSFIC	Bangladesh Sugar and Food Industries Corporation
BTCSL	Biogas Technology Consulting Services Ltd
C&F	Chicks & Feeds Limited
CBG	Compresses Biogas (Compressed Biomethane)
CBM	Coal bed methane
CCAMP	Climate Change Adaptation and Mitigation Programme
CCR	Charnes-Cooper-Rhodes
CCTF	Climate Change Trust Fund
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CNG	Compressed Natural Gas
CRS	Constant Returns to Scale

CSES	Centre for Sustainable Environmental Sanitation
CSTR	Completely Stirred Tank Reactor
DAE	Department of Agricultural Extension
DANIDA	Danish International Development Agency
DEA	Data Envelope Analysis
DLS	Department of Livestock Services
DMU	Decision Making Units
DoE	Department of Environment
EA	Environmental Authorities
EDGP	Expected daily biogas production
EE	Energy Efficiency
EF	Efficient Frontier
EIA	Environmental Impact Assessment
FIT	Feed in grid Tariffs
FnBB	Fördergesellschaft für nachhaltige Biogas und Bioenergie Nutzung e.V.
FSM	Faecal Sludge Management
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GENSET	Generator Set
GERBIO	German Society for Sustainable Biogas and Bioenergy Utilisation
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GoB	Government of Bangladesh
HEEEC	Hangzhou Energy and Environment Engineering Cooperation
HRT	Hydraulic retention time
IBBK	Internationales Biogas und Bioenergie Kompentenzzentrum
IDCOL	Infrastructure Development Company Limited
IFC	International Finance Cooperation
IFRD	Institute of Fuel Research and Development
ILO	International Labour Organization
JCM	Joint Crediting Mechanism

JDEC	Jinan Diesel Engine Company
JICA	Japanese International Cooperation Agency
KfW	Kreditanstalt fuer Wiederaufbau
LCPO	Loan and Construction Partner Organisation
LGED	Local Government Engineering Department
LPG	Liquefied Petrol Gas
MPEMR	Ministry of Power, Energy, and Mineral Resources
MSW	Municipal Solid Waste
NAMA	Nationally Appropriate Mitigation Actions
NCCWE	National Coordination Committee for Workers Education
NDBMP	National Domestic Biogas and Manure program
NGO	Non-governmental Organisation
NLG	Natural liquid gas
PKSF	Palli Karma-Sahayak Foundation
PRAN	Programme for Rural Advancement Nationally
PV	Photovoltaic
RDA	Rural Development Academy
REA	Renewable Energy Association
RERD	Renewable Energy Research & Development
RFL	Rangpur Foundry Limited
RMS	Record Management System
S.R.O.	Statutory Regulatory Order
SBAL	Seed Bangla Limited
SED	Sustainable Energy for Development
SNV	Stichting Nederlandes Vrijwilligers
SPL	Summit Power Limited
SRDI	Soil Resource Development Institute
SREDA	Sustainable and Renewable Energy Development Authority
TS	Total Solid
UCG	Underground coal transmitted into gas
USTB	University of Science and Technology Beijing
VGD	Vulnerable Group Development
VRS	Variable returns to scale
W2E or WtE	Waste to Energy

EXECUTIVE SUMMARY

The present study-project: “Situation analysis of the agro-industrial biogas subsector in Bangladesh” was undertaken under contracts from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH by a Bangladesh-German cooperation of the two biogas associations: Bangladesh Biogas Development Foundation (BBDF), and the German Society for Sustainable Biogas and Bioenergy Utilisation (GERBIO) from December 2015 to July 2016, to gather sufficient information from a large variety of stakeholders to conclude whether there is a feasible market for commercial agro-industrial biogas systems under energy, environmental and fertilizer aspects, keeping in mind also socio-economic development and animal welfare issues. The final study report therefore provides an outline to induce a future sector review for the commercial biogas subsector development. To complete this summary, under chapter 14 a set of conclusions and recommendation is tabled. This summary was presented in a public workshop under the Sustainable and Renewable Energy Development Authorities (SREDA) on 18 December 2016 in Dhaka and additional recommendations from the audience were added.

The consultant team formed by expert members from the Bangladesh Biogas Development Foundation (BBDF) and the German Society for Sustainable Biogas and Bioenergy Utilisation (GERBIO/FnBB) was led by Heinz-Peter Mang, Guest-Professor for Bioenergy and Eco-Sanitation at the Centre for Sustainable Environmental Sanitation at the University of Science and Technology Beijing.

Biogas production covers usually the following plant types:

- Wastewater and sewage sludge treatment plants (not covered within the study),
- Bio-waste – co-digestion or mono-digestion of food waste and other types of bio-waste (not covered within the study),
- Agriculture – digestion at farms (mainly manure, crop residues, and energy crops),
- Industrial – digestion of waste stream from various industries (e.g. food industries),
- Landfill – landfills with collection of the landfill gas (not covered with the study).

The scope of the study covers an assessment of the pre-conditions for a feasible market for agricultural and industrial commercial biogas subsectors in Bangladesh, considering both the demand and supply end, and resulting in the findings that – although the demand on behalf of agro-industries exists, neither the needed technology could be supplied, nor an enabling environment is yet facilitated by policies and authorities. Several advancements need to be made before it is really viable however a few developers and investors are assessing already the market. The Government of Bangladesh (GoB) had announced a **renewable energy policy**, and a plan to increase its share in power generation by 10% in 2020 (*2008 Renewable Energy Policy: The renewable energy policy envisions that 5% (800 MW) of total energy production was planned to be achieved by 2015 and 10% (2000 MW) by 2020/21 and 4000 MW by 2030.)* End 2014, the national capacity of renewable energy based power reached around 405 MW - around 2.53%.

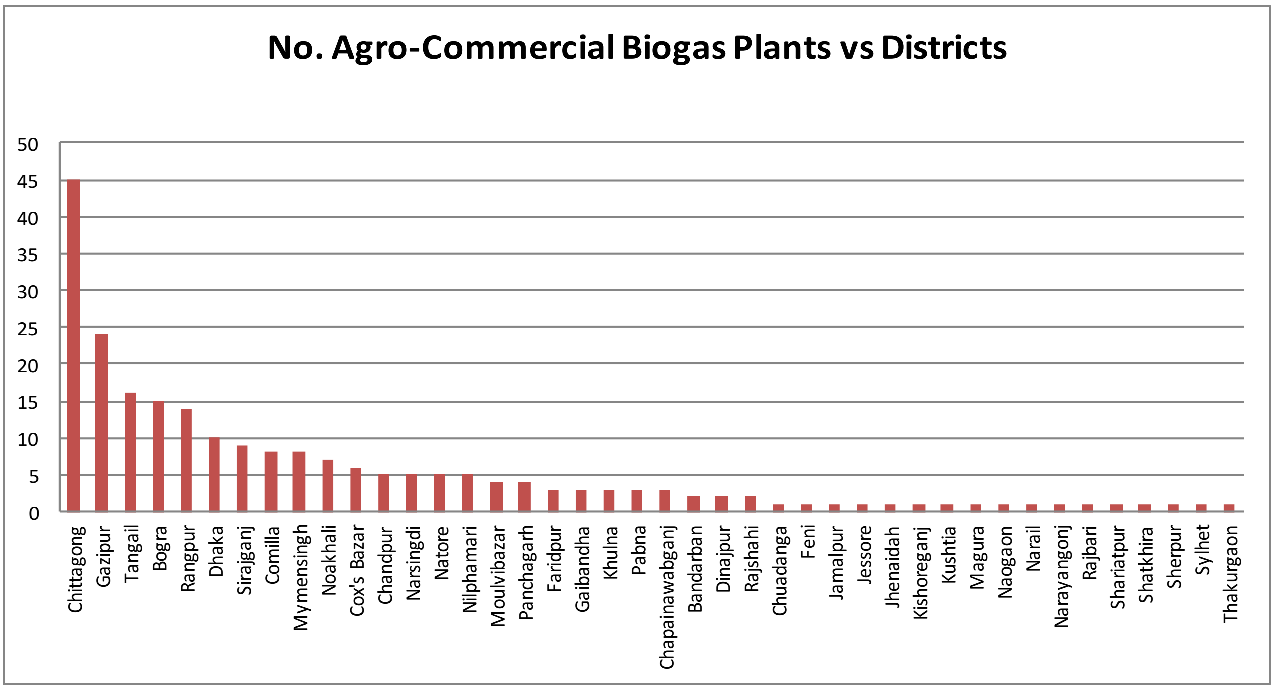
After a brief literature research, 228 larger poultry and cow dung based biogas plants have been physically identified, operating in Bangladesh. Other industrial biogas plants could not have been identified. Finally, after screening, only 130 biogas plant systems remained, others were multiple interconnected biogas plants on one farm site, or no more in operation. 30 such larger plant systems have been visited by the consultants in the period of 2016; overall 70 plant owners and operators have been interviewed by phone or in person. 9 plants – analysed based on owners or operators given data's - were identified as best performing, hence providing a benchmark for agro-industrial biogas plants in Bangladesh.

As worldwide recognized, commercially driven and productive use of renewable energy aims providing (primarily) renewable energy to sustainably serve the demand for income generation activities. It is specifically suitable for producing electricity, mechanical power, transport fuel, or heat, and/or fertilizer/ soil improver, on medium to large scale.

Therefore, agro-industrial biogas plants in Bangladesh are per chosen definition "Commercial Biogas Plants or Biogas Plant Systems" with an expected daily biogas production of more than $50m^3$, or 300kWh/d thermal production capacity, or about 100kWh/d electricity production capacity.[1] In Bangladesh, this type and sizes of

[1] Based on the assumption that $1m^3$ biogas has $6kWh/m^3$ thermal energy and could produce through GENSETs $2kWh/m^3$ electricity. Depending of the efficiency performance (defined in m^3 biogas per day/m^3 fermenter volume), the required construction volume would range from

plants are distributed across the country, with most of such plants constructed in Chittagong and Gazipur districts.



The process of data collection to perform the “Data Envelopment Analysis” (DEA) to find the best performing biogas plants, and achieving benchmarks for agro-industrial biogas plants encountered various challenges:

(1) None of the (interviewed and visited) agro-industrial biogas plants in Bangladesh is equipped with measurement devices, which would provide the data for performance monitoring: no gas flow meter, no meter for own produced operational electricity consumption or production, no gas quality control device.

(2) None of the biogas system operators or owners (enterprises) provided detailed economic and financial data (capex & opex) to the study team, which would have facilitated a detailed economic or financial analysis of the biogas systems and a general sensitivity analysis.

Besides technical and basic economic analysis, the study presents an analysis of the perspectives, perceptions and opinions of 12 Key Informants, and 9 out of 14 identified service providers, both financial and technical, 30 visited owners and

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50m3 (based on 1.0m^3/m^3) to 250m^3 (based on 0.2m^3/m^3), in Bangladesh usually defined with 100-125m^3 (based on 0.4-0.5m3/m3).

operators of agro-industrial biogas systems, and 25 interested potential biogas clients.

In summary, the study revealed that

(1) No unified data base on agro-industrial biogas plants exists in Bangladesh.

(2) The agro-industrial biogas sector in Bangladesh is strongly influenced by the national experiences with domestic household biogas models and related technical guidelines; both technical and financial service providers have only limited information about recent technological developments in the international biogas industry for medium and large scale biogas plants.

(3) The technical service providers are aware that they lack knowledge to implement modern state-of-art biogas technologies in Bangladesh. Only two biogas plants found are equipped with digester mixing devices, and are designed as thermal insulated CSTR (Continuously Stirred Tank Reactor).[2] Technical service providers ask either for exposure visits and intensive training from international providers, or for joint ventures with international biogas enterprises.

(4) Financial services for agro-industrial biogas plants are limited to programs sponsored by international donors, and these are offered in competition with different grant and technical assistance components, and varying loan conditions; the feasibility studies analysed are mainly based on Bangladesh academic laboratory research, literature from India and China, and theoretical values; nearly no bio-methane potential tests of specific feedstock material were performed before designing a larger biogas unit.

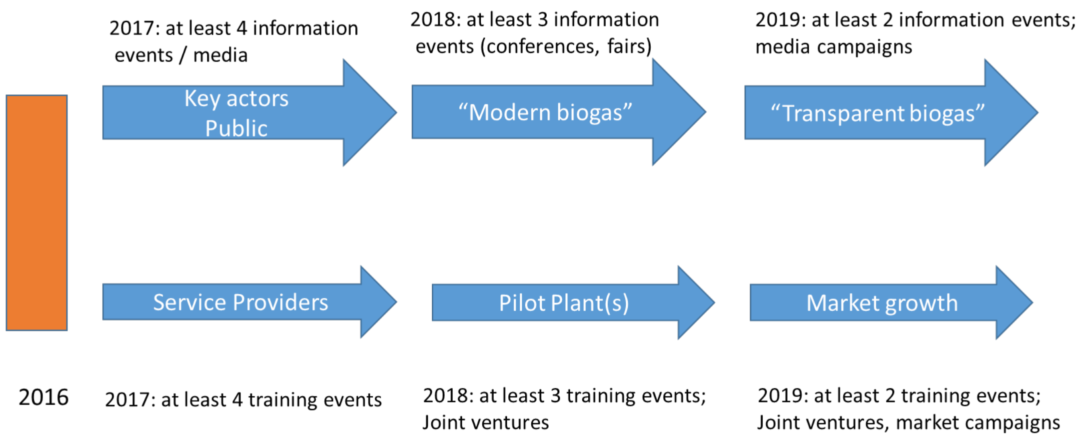
(5) The theoretical market potential for agro-industrial biogas plants in the country could be currently estimated at about 130,000 systems. From these figure, per Bangladesh Bureau of Statistics (BBS, 2010), there are more than 70,000

[2] Worldwide, in bigger biogas plants, mechanical agitation is dominating the market for stirring fermenting substrates from agricultural origin. One Dry Fermentation biogas plant under construction and designed for sorted municipal organic waste was not considered in this study frame.

commercial poultry farms in Bangladesh, with about 1,700 farms having more than 10,000 birds. Bangladesh therefore has good potential for biogas based electricity projects in poultry farms. Municipal and industrial waste-to-energy plants and sewage or faecal sludge fed plants were explicitly excluded from the scope of the assessment.

The study team therefore proposes a **road map** with two parallel tracks towards a sustainable agro-industrial biogas market: track 1 is reserved for service providers; track 2 is dedicated to sector key actors and the public.

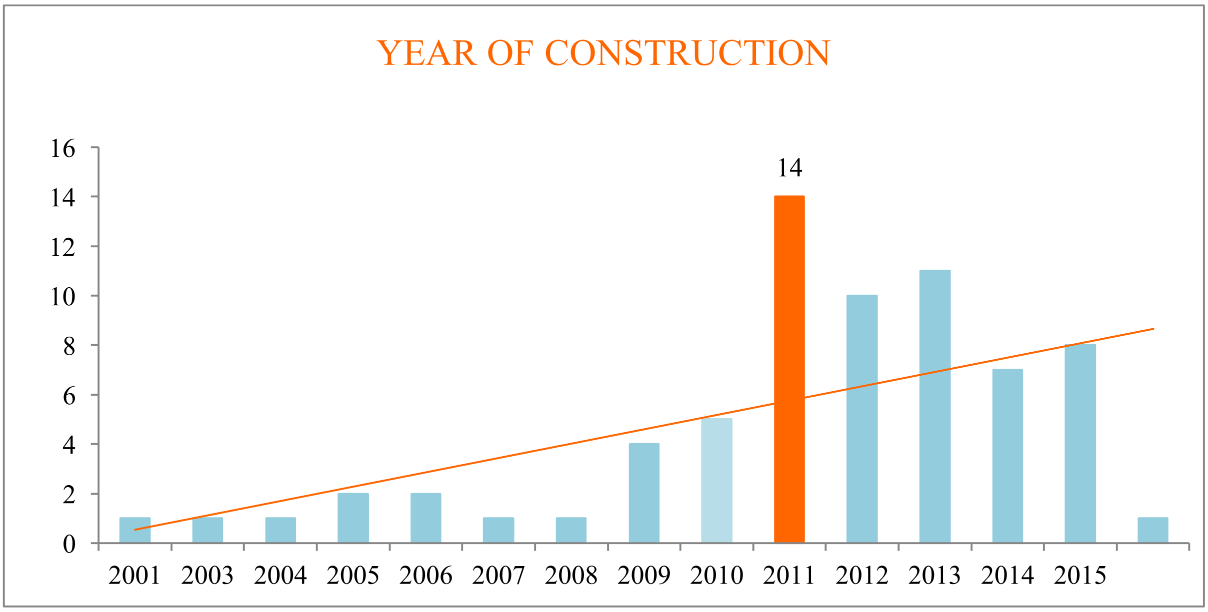
If one track will be neglected, the other track by itself and its own efforts will not be able to achieve the goal of a sustainable agro-industrial large scale biogas plants.



The primary challenge in the Bangladesh energy sector is to establish universal electricity access by 2021.

Although private sector investors have realized that the investment in biogas technology pays off – for both captive and emergency power generation, there is a financial barrier to large scale technology dissemination, as the idea is new to banks and financial institutions. To help overcome this barrier, GIZ has signed a memorandum of understanding with Infrastructure Development Company Limited (IDCOL) and the International Finance Corporation (IDC), which will both provide financing for larger commercial biogas plants. But financial incentives alone will not develop the market. During the interviews and plant visits it became obvious that significant updates in knowledge and intensified contacts to international biogas enterprises are required inputs as well as are changes in policies linked to biogas technology promotion. These include at least import and duty regulations, agricultural, environmental protection, and fertilizer policies.

The statistical analysis revealed that construction of Agro-Industrial-Biogas plants (AIBP) in Bangladesh increased from 2009 onwards, one year after the “Renewable Energy Policy of Bangladesh” was approved; 2011, 2012 and 2013 were the years when most of AIBP construction took place.



In addition to sector specific trainings and policy changes, the public should receive appropriate information on biogas technologies as one of the most efficient and flexible renewable energies. Biogas is a flexible fuel that can be used as a buffer in the renewable energy mix and contribute to a lower dependency on outside energy sources. With an increasing share of renewables on the one hand side and a limited availability of biomass on the other hand, the provision of bioenergy must consider the demands of the future energy system with high shares of fluctuating wind and solar power. This includes new concepts for biogas and bio-methane, while for the electricity sector, the demand for more flexible provision might take place in the years to come. (1) **Demand driven biogas systems** increase the production of electricity from biogas facilities at times of high demand for electricity, or store biogas temporarily at times of low electricity demand. (2) **Power to gas systems** when demand for electricity is less than supply of electricity to the electricity grid, allowing conversion of surplus electricity to gas. For biogas market implementation adopted regulatory framework and price signals from electricity markets are necessary.

1. INTRODUCTION

1.1 RATIONALE AND OBJECTIVE

The Sustainable Energy for Development (SED) program supported by the Ministry of Power, Energy, and Mineral Resources (MPEMR) and the German Federal Ministry for Economic Cooperation and Development (BMZ) implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is promoting since 2007 the use of renewable energy, as well as the efficient use of energy. The program supports the newly established Bangladesh Sustainable and Renewable Energy Development Authority (SREDA) from its inception. GIZ is working with state institutions to encourage the dissemination and adaptation of new technologies.

Although private sector investors have realized that the investment in biogas technology pays off – for both captive and emergency power generation, there is a financial barrier to large scale technology dissemination, as the idea is new to banks and financial institutions. To help overcome this barrier, GIZ has signed a memorandum of understanding with Infrastructure Development Company Limited (IDCOL) and the International Finance Corporation, which will provide financing for commercial biogas plants. The first commercial biogas plants that obtained a loan from IDCOL in 2008 was producing captive electricity. To accelerate the roll-out further, GIZ is also coordinating advisory services for appropriate banks, such as Bangladesh Krishi (agricultural) Bank and other banks/financial institutions in the public and private sectors. Since 2007, GIZ has supported the design and installation of about 2,000 biogas plants in slaughterhouses, on dairy and poultry farms, and at boarding schools. Many of them produce biogas also on a commercial scale, which is used for institutional cooking and/or generating electricity.

The objective of the present study-project: “Situation analysis of the agro-industrial biogas subsector in Bangladesh” is to gather sufficient information from a large variety of stakeholders to conclude whether there is a feasible market for commercial biogas under energy, environmental and fertilizer aspects or not, keeping in mind also socio-economic development and animal welfare issues. And if so, the final study report should provide a detailed outline to design a future sector review for the commercial biogas subsector development.

1.2 Scope of Study

To develop the sector, it is therefore essential to conduct within the present study a thorough investigation to know the total stock of at least the agro-industrial biogas plants in the country, their status and the lessons learned by owners and operators to develop a road map for sustainable sector and market development. The scope of work requires a full understanding of the commercial biogas approach in Bangladesh, and the barriers to its development. The overall intention of the leading actors in the sector is to gradually introduce stricter environmental policies, to provide better service systems, improve the financial policies that supports the construction and follow-up service of commercial biogas projects, promote the use of standardized engineering equipment and materials and standards for plant construction and production.

The scope of the situation analysis covers

1. Assessment of the pre-conditions for a feasible market for a commercial biogas subsector in Bangladesh, considering both the demand and supply end.
2. Assessment of the readiness of service providers, service facilities, the service recipient and the policy environment to respond for commercial biogas sector development. This includes:
   - Exploring potential clients' perceptions of their needs, the options available to those who have already or plan to invest in commercial biogas plants in Bangladesh.
   - Exploring service providers' perceptions of their capacity to offer quality services including planning and designing, construction, and maintenance; considering also secondary service provisions, such as bio-slurry management.
   - Assessing the service providers' technical and commercial competence, and business development strategies.
   - Describing the status of policies, strategies and laws in Bangladesh to promote commercial biogas technologies; as well as the client-friendliness of laws and policies
   - The financial structure, availability of working capital, risk mitigation measures in long-term credit for businesses that are susceptible to

inherent business risks, as bird flu attacks in poultry firms, will also be part of the scope.

3. Provide recommendations and insights as a way forward to conduct an in-depth sector review.

1.3 RECIPIENT OF THE STUDY: THE SUSTAINABLE AND RENEWABLE ENERGY DEVELOPMENT AUTHORITY, SREDA

The Sustainable and Renewable Energy Development Authority (SREDA) was formed by Statutory Regulatory Order (S.R.O.) No. 69 Law/2014, in exercise of the powers conferred by section 29 of the Sustainable and Renewable Energy Development Authority Act, 2012 (Act No. 48 of 2012), of the Bangladesh Parliament, on 10th December 2012 as a nodal agency to promote, facilitate and disseminate Renewable Energy (RE) and Energy Efficiency (EE) to ensure the energy security of the country. The Sustainable and Renewable Energy Development Authority (SREDA) Act in 2012 aimed to facilitate, regulate and to promote all aspects of renewable energy and energy conservation including the development of sustainable energy supply solutions.

SREDA started working officially on 22nd May 2014 to become a fully functional national coordination body. This included developing a roadmap towards its vision "*to promote sustainable energy and build energy conscious society to ensure energy security and to reduce carbon emission*." The institution is working under Power Division of the Ministry of Power, Energy and Mineral Resources (MPEMR) of the Government of the People's Republic of Bangladesh.

The Government of Bangladesh (GoB) had announced a renewable energy policy and a plan to increase its share in power generation by 10 percent in 2020 (2008 Renewable Energy Policy). And the primary challenge in the Bangladesh energy sector is to provide universal electricity access by 2021.

The GoB has also set renewable energy development targets for several technologies for each year from 2015 to 2021 ("RE Development Targets"). The RE Development Targets call for an additional 3,100 MW of RE capacity to be installed by 2021. Most of the new capacity will be provided by solar (1,676 MW, or 54 percent) and wind (1,370 MW, or 44 percent). There are also targets for waste-to-energy (including biogas, landfill biogas (70% of landfill gas captured and used for electricity generation), and incineration) (40 MW), biomass (7 MW), biogas (7 MW) and hydro (4 MW). As per proposed Energy Efficiency (EE) Master Plan, the energy saving target would be 15% by 2021, and 20% by 2030.

Functions of SREDA

The main functions of SREDA are to

- coordinate renewable energy and energy efficiency issues of GoB
- promote sustainable energy production, supply and use
- standardize products for RE and EE
- pilot new technologies, and take initiatives for the dissemination of best practices
- create an enabling environment for the investors
- conduct localized research and development on RE and EE
- create awareness and capacity for RE and EE
- establish linkages with regional and international organizations in the RE-sector.

1.4 STUDY IMPLEMENTATION PARTNERS

Under the direct coordination of the GIZ office in Bangladesh, an international consortium was formed consisting of two biogas associations (Bangladesh and Germany) and one German biogas expert based in China as lead consultant.

1.4.1 BANGLADESH BIOGAS DEVELOPMENT FOUNDATION, BBDF

In March 2008, the present Chairman of BBDF, Mr. Gofran, attended the Washington International Renewable Energy Conference and came to know the achievements of the international community in the field of RE and EE, especially in biogas technologies. On his return to Bangladesh, he convened a meeting of sector stakeholders, service providers and experts in the field of biogas technology. In this meeting, the participants decided to form a forum of concerned organizations and individuals under the name of ‘Bangladesh Biogas Development Foundation (BBDF)’. BBDF is an independent, non-political, non-profit, social and non-governmental organization working in the field of biogas technology. It is registered under Joint Stock Company. It is run by an executive committee of 13 members elected for a period of two years. It was established in 2008 and at present it has 143 individual members including 14 lifetime members.

Objectives of the forum

- Ensure energy security in rural settlements
- Identify local initiatives in the field of biogas technology and support their promotion
- Identify best practices at home and abroad and disseminate information
- Conduct R&D to develop biogas technology
- Identify barriers in disseminating biogas technology and take steps to resolve
- Social mobilization and awareness raising
- Capacity building through training
- Stop rural to urban migration by creating employment in the rural
- Policy development and advocacy

Activities:

- Arranging for local-to-local dialogue
- Organizing experience sharing meetings
- Arranging workshops and seminars
- Study tours
- Feasibility / pre-investment studies for biogas technology projects
- Resource survey
- Rural employment and biogas technology
- Environmental planning and management
- Rural energy access through wide dissemination of biogas technology
- Inspection and testing of biogas plants
- Human resource development and capacity training
- Information dissemination

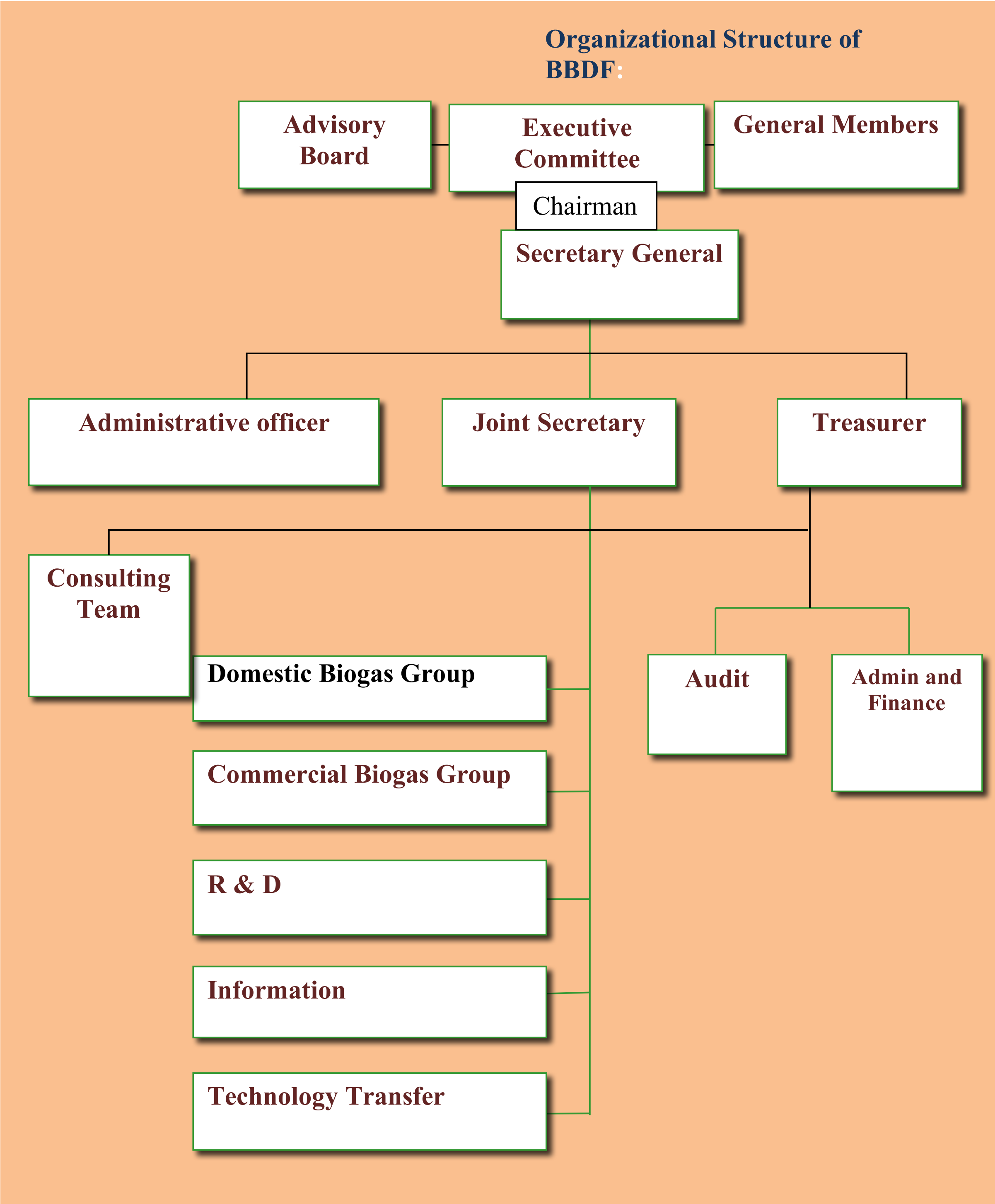


FIGURE 1: ORGANIZATIONAL STRUCTURE OF BBDF

Achievements of BBDF:

- Contributed to formulating National Renewable Energy Policy 2008 and 2012
- Contributed to establishment of an agency for the implementation of National Renewable Energy Policy

- Organized workshops, seminars, and opinion sharing meetings to draw public attention towards renewable energies including biogas technology
- Awarded best performers in the field of biogas technology
- Providing advisory services to service providers and customers
- Providing training in the field of biogas technology for human resource development.

1.4.2 German Society for sustainable Biogas and Bioenergy Utilisation, GERBIO

The German Society for Sustainable Biogas and Bioenergy Utilisation (GERBIO) was founded in 2001 and legally registered 2003 under its German name “Fördergesellschaft für nachhaltige Biogas und Bio-Energienutzung (FnBB) e.V.” and under its English name GERBIO, to promote and distribute information about the sustainable generation and use of energy made from organic residues. The goal of the professional association is to enhance the entire cycle of production and usage of bioenergy, from production of organic biomass and bioenergy to recycling of residual materials, within the framework of economically, ecologically, and socially acceptable and effective means. GERBIO does this by interdisciplinary, multi-professional national and international conferences, training courses, consulting services, and active networking. In cooperation with various organizations GERBIO forms the German and European political framework for bioenergy. When new laws, or changes in existing laws emerge, GERBIO acts, representing members' interests in a timely manner through personal talks and dialogue with the decision-making authorities on local, national, and international levels, as well as through technical and scientifically based petitions. GERBIO’s professional competence is increasingly accepted by German public stakeholders, as well as by national and international organizations. Beside Europe, members of GERBIO are also as consultants and trainers involved in the biogas development in Asia, Africa, Australia and the Pacific Islands and Latin America. In summary, GERBIO is

- A network of international experts to promote worldwide biogas and biomass energy technologies:
- Registered in 2003 as non-profit Non-Governmental Organisation
- Promoting the sustainable generation and use of bioenergy through training and sensitization campaigns

- Promoting closed-loop approaches for an ecological economy

In cooperation with one of its member, the International Biogas and Bioenergy Competence Centre (Internationales Biogas und Bioenergie Kompentenzzentrum (IBBK) GmbH), GERBIO – since its foundation – is organizing international annual biogas training courses at the University of Agriculture in Stuttgart-Hohenheim, Germany; in the last 5 years in cooperation with the Renewable Energy Association (REA) in UK, since 2014 in South Africa, and since 2016 in Malaysia.

1.4.3 LEAD CONSULTANT, PROF. DIPL-ING. HEINZ-PETER MANG

Mr. Heinz-Peter Mang was appointed by GIZ as the international lead consultant for the study. He is an expert on Bioenergy and Eco-Sanitation having more than 35 years of worldwide experience in relevant fields involving biogas and bioenergy technologies, waste and wastewater treatment, digestate reuse and ecological sanitation. He obtained his Dipl.-Ing. (M.Eng.) on Thermal Engineering from the University of Applied Science in Giessen, Germany in 1980, and is working since 2008 as Guest-Professor for Biogas and Sustainable Sanitation and as Technical Manager of the Centre for Sustainable Environmental Sanitation (CSES) in the Department for Environmental Engineering at the University of Science and Technology Beijing (USTB). Mr. Mang is also a co-founder of GERBIO (2001), and the German Biogas Associations (Fachverband Biogas e.V., 1992).

He has provided and is providing consultancy and engineering services to various biogas projects in various capacities, and in many countries on all 5 continents, nowadays he is working beside China, also in/for Nepal, DPR Korea, Burkina Faso, Lesotho, Samoa, Cuba, Lebanon, Jordan, and Germany. Currently – and since 2011 - he is also working in Bangladesh as intermittent biogas and biomass energy consultant for the government owned Infrastructure Development Company Limited – IDCOL, as Co-Investigator at the Bangladesh Agricultural University (BAU) - co-supervising also a Bangladesh PhD in biogas research, and as Faecal Sludge Management (FSM) consultant for SNV-Bangladesh.

1.5 METHODOLOGIES AND SCHEDULE

1.5.1 TEAM, TASKS, TOOLS AND TIME LINES

1.5.1.1 TEAM

The study team is composed by nine biogas experts from Bangladesh, Germany and Ecuador.

TABLE 1: COMPOSITION OF STUDY TEAM

Position	Name	Experience
Lead Consultant	Prof. Dipl.-Ing. Heinz-Peter Mang	Energy Engineer / International Biogas Expert (Germany - China)
BBDF team	MSc. Shamsul Haque	Chemical Scientist / Biogas Expert
	MSc. Mokarrem Billa Chowdhury	Biochemical Scientist / Biogas Expert
	M.Sc. Md. Naimul Haque	Chemical Scientist / Biogas Expert
	Mr. Shahed Israil Khan	Renewable Energy Advisor
GERBIO team	Mrs. Dipl.-Ing. Jenny Aragundy	Environmental Engineer / Biogas Expert (Ecuador)
	Dr. Humayun Kabir	Agricultural Biogas Expert
	Mrs. Elisabeth Huba (M.A.)	Social Scientist / Biogas Expert
	Dipl.-Biol. Michael Köttner	Biologist / Biogas Expert

1.5.1.2 TASKS, TOOLS AND TIME LINES

The team worked on the defined tasks for the analysis of current situation and market potential with several tools and methodologies within the agreed and twice extended time lines from end 2015 to early 2017.

TABLE 2: TASKS, TOOLS AND SCHEDULE

No.	ToR requested scope of the situation analysis	Approach, methodologies, tools	Time schedule and/ or deliverables
		Kick-off meeting	Dec. 6, 2015
0	Preparing methodology, interview and assessment guidelines	Revise and adapt Bangladesh and international biogas plant performance assessments and market study tools	Dec. 7, 2015 to Feb. 01, 2016 Interview outlines for data collection and analysis
1a	Making appointments with sector stakeholders	Desk study to identify potential agro-industrial biogas clients and their associations, as well as decision making key stakeholders for the biogas sector.	Draft list of biogas relevant industries presented to GIZ
		Stakeholder workshops to present (1) national and international agro-industrial biogas technology; (2) obtain general opinions from potential clients and strategic allies for agro-industrial biogas market	Feb 3 & 8, 2016 in GIZ office, Dhaka, with representatives from 26 (potential and existing) stakeholders
		After having obtained an official introduction letter from SREDA in February 2016, appointments and written statements obtained from 6 key resource persons or institutions have been made.	Interviews conducted in February and March 2016, completed in May 2016
1b	Assess whether there is a feasible market for a commercial biogas subsector in Bangladesh, considering both the demand and supply.	Secondary literature review and key informant interviews representing the demand and supply side.	Dec. 10, 2015 to end May, 2016
		Internal briefing meetings with SED-GIZ-Bangladesh	Jan. 27 & Feb 9, 2016

No.	ToR requested scope of the situation analysis	Approach, methodologies, tools	Time schedule and/ or deliverables
		Meeting with SREDA and sector key stakeholders to clarify the term “commercial biogas”	Feb. 16, 2016: but agreement on definition postponed
2a	Assessing service providers’ perceptions of their readiness to offer services from the planning phase, system design to construction, operation, maintenance, and after-sale services.	Definition of “Service Provider”	Feb. 9, 2016
		Handout / guideline for capacity needs assessment among technical and financial service providers	Feb. 13, 2016
		Agree with GIZ on service providers to be included in situation analysis	Feb 9, 2016
	Assessing the service providers’ technical competence, maintenance and repair work capacity, and strategies for good customer relations and further business development.	Meetings / Interviews with technical and financial service providers – up to now 6 meetings / interviews.	Feb 16, 18 & 22, Mar 7, 2016
2b	Assessment of clients’ perceptions of their needs, and the options available to those who plan to invest in large-scale commercial biogas plants in Bangladesh.	List of commercial / agro-industrial biogas plants based on literature review and updated information from service providers – in total 228 biogas plants from 6 to 2700m^3 expected daily biogas production	Dec 7, 2015 to Feb 29, 2016
		Agree with GIZ that in total 30 biogas systems should be analysed and their performance documented	Feb 9, 2016

No.	ToR requested scope of the situation analysis	Approach, methodologies, tools	Time schedule and/ or deliverables
		Site visits to gather Lessons Learned from owners of existing agro-industrial biogas systems, and to analyse the weak points of the technological concept –30 site visits	Dec 7, 2015 - Mar 25, 2016: Systematic documentation to allow for overall analysis and recommendations for improvements
2c	Secondary services, like bioslurry management, production and marketing of organic fertiliser – currently provided or needed for future market development.	Interviews with agro-industrial enterprises (poultry (broiler and layer)), dairy, cattle, fish, meat processing, distilleries, sugar), including both biogas plant owners and future potential clients.	Dec 7, 2015 - Mar 25, 2016: 30 commercial biogas plants (medium and large scale) visited by the study team, documented with short impression reports or questionnaires.
		Agro-industrial biogas plants built before 2012 will be analysed in view of the repair work and maintenance done to keep they operational.	Draft Interim Report: end of March 2016 to be finalized based on SED team feedback until end April 2016.
2d	Describing the status of policy, strategies and laws in Bangladesh to promote agro-commercial biogas technology; as well as the client-friendliness of laws and policies, regarding (rural) grid-connection policy to feed-in-grid electricity, captive power use, biomethane as transport fuel, greenhouse gas emission reduction benefits, wastewater treatment co-benefits, soil improver and organic fertilizer	Literature review and key informant interviews	Literature review started Dec 7, 2015
			Key informant interviews started on Feb 3, 2016, completed end May 2016

No.	ToR requested scope of the situation analysis	Approach, methodologies, tools	Time schedule and/ or deliverables
2e	Final draft report with recommendations and preliminary conclusions	In-depth analysis within study team; recommendations for action plan for sector empowerment; draft road map for market development.	Inputs received from BBDF are included up to mid-July 2016, draft final report delivered August 2016, and revised and updated based on feedbacks received in November 2016.
3	Conclusions for future market potential and market development	In-depth analysis with SREDA selected stakeholders, SREDA, study team and GIZ during 'result workshop'; discussing recommendations for action plan for sector empowerment; road map for market development.	Present final study report by lead consultant in a workshop on December 18, 2016, at SREDA in Dhaka. Updating final report with recommendations from the audience in the first months of 2017.

2. DESK STUDY, DEFINITIONS AND LITERATURE BASED INVESTIGATION

2.1 DEFINITION OF DOMESTIC BIOGAS PLANTS

Household biogas plants are defined in Bangladesh by an “expected daily biogas production” (EDGP) of up to $4.8m^3$. As there is no definition for commercial biogas plants so far agreed upon, some stakeholders consider any biogas plant with an expected daily biogas production of more than $4.8m^3$ as a commercial one. This definition guided the analysis. However, it was found in former field visits that the biogas produced in household biogas plants of $3.2m^3$ and $4.8m^3$ daily biogas production capacities are sometimes already used for cash income generation, such as commercial cooking fuel supply for neighbour families (biogas mini-grid), or as small power production unit (GENSETs with 1 to $4kW_{el}$ electrical capacity) feeding commercial electricity mini-grids in the neighbourhood.

In addition, this definition (up to $4.8m^3$ EDGP = non-commercial; beyond $4.8m^3$ EDGP = commercial) would already include biogas plants with total construction volumes from $12m^3$ upwards.

A meeting with the most relevant actors in the biogas sector on Feb. 16, 2016 in SREDA offices could be understood as the official start of the discussion which should lead to an agreement on what is meant with ‘commercial’ biogas plants in Bangladesh. Nevertheless, ‘agro-industrial’ biogas plants are defined by the feedstock / organic matter / substrate which is used to generate biogas. To date, agro-industrial biogas plants in Bangladesh are fed with either poultry litter or cattle dung; they are all located at commercial farms. With an expected daily biogas production between $50m^3$ to $2700m^3$ per system, 130 identified agro-industrial biogas systems are operated in Bangladesh in the year 2016.

2.1.1 OVERVIEW OF THE DOMESTIC BIOGAS DEVELOPMENT IN BANGLADESH

Biogas was first introduced in Bangladesh in 1972 by Dr. M. A. Karim, Professor at the Bangladesh Agricultural University, Mymensingh campus. This plant was a floating-dome type and the size was $3m^3$ digester volume. Later, another plant of $6m^3$ digester volume was constructed to serve the purpose of lighting and cooking for a family with 6 members. Since Dr. Karim’s pioneering initiative, the dissemination of biogas has been relatively slow. In 1974, another plant was constructed at Bangladesh Academy for Rural Development (BARD), Comilla. In 1976, the Institute of Fuel Research and Development (IFRD) constructed a family-size biogas plant at the Bangladesh Council of Scientific and Industrial Research (BCSIR) campus in Dhanmondi, Dhaka.

In 1981, Department of Environment (DoE) started a program through which about 150 floating dome and 110 fixed-dome biogas plants were installed. Other efforts were undertaken by the Bangladesh Small and Cottage Industries Corporation (BSCIC), the Local Government Engineering Department (LGED), and the Department of Livestock Services (DLS) of the Bangladesh Ministry of Fisheries and Livestock.

Under the “Fuel Saving Project’, implemented during 1989-1991, LGED supported the establishment of an ecological village (Amgram, Madaripur district) among others by converting 95 latrines into feedstock suppliers for family biogas plants. Several programs followed, but all of them concentrated on household biogas sizes.

Under Biogas pilot plant project (1st and 2nd phase) implemented by IFRD of BCSIR, a total of 21858 fixed dome form biogas plant were constructed throughout the country during 1997-2004

IDCOL with the support of SNV Netherlands, KfW and World Bank is implementing the National Domestic Biogas and Manure program (NDBMP) since 2006; in the framework of this program over 42,000 plants of different household related sizes (ranging 1.2, 1.6, 2.0, 2.4, 3.2 & 4.8m^3) have been constructed by IDCOL’s partner organizations.

Institute of Fuel Research and Development (IFRD) of the Bangladesh Council of Scientific and Industrial Research (BCSIR) has completed the 1st phase of “Mitigation of Carbon emission and extension of alternative energy usage through dissemination of biogas plant” project under the Climate Change Trust Fund. Within this project, 2800 domestic fixed dome biogas plants were installed in 7 districts, while in a 2nd phase of this project 5000 biogas plants in 15 districts was installed. A household biogas program is also undertaken by the Youth Department of the Ministry of Youth and Sports in 64 districts.

At present, the total number of small household biogas plants achieved nowadays about 100,000 (BBDF, 2015), reaching 0.4 percent of all rural households in Bangladesh (based on BBS census figures from 2011: total households in Bangladesh 31,705,684, and 25,535,877 in rural areas). The majority serves for rural farm households, constructed by many trained technical service providers with support from different implementation agencies like Bangladesh Council for Scientific and Industrial Research (BCSIR), Local Government Engineering Department (LGED), Grameen Shakti, Ministry of Youth, Rural Development Academy (RDA) Bogra, Infrastructure Development Company Limited (IDCOL), and the Bangladesh Climate Change Trust Fund (CCTF) under the Ministry of Environment and Forests.

The Rural Development Academy (RDA), Bogra, as a specialized rural development institution for training, research and action research has been implementing some projects to integrate water management projects, poverty alleviation through livestock management and biogas bottling project and command area development using surface water for rural livelihood improvement. Under these projects 31,000 people throughout the country have been benefited through installation of community biogas plants.

At present, the rural farm household cooking energy demand is defined in Bangladesh with a maximum of 4.8m^3 potential biogas production per day, although 1.5m^3 has shown as sufficient to cover the usual daily cooking requirements of a rural family.

2.2 AGRO-INDUSTRIAL BIOGAS SYSTEMS: DEFINITION AND ASSESSMENT

With increasing size, the complexity of a biogas system multiplies. At this stage it is necessary to define the term “Commercial Biogas Plant” explicitly, with stratified categorization and specific indicators, including the size and design of biogas systems, the end use of the products such as biogas-to-power, feed-in-(gas) grid or upgrading of biogas to bio-methane for vehicle fuel, or bottling of biogas, type of organic matter used as feedstock, the appropriate business and operating model, and – last but not least, the management of the digestate (bioslurry).

As worldwide recognized, commercially driven and productive use of renewable energy aims providing (primarily) renewable energy to sustainably serve the demand for income generation activities. It is specifically suitable for producing electricity, mechanical power, transport fuel, heat and/or fertilizer/ soil improver on medium to large scale.

Consequently, agro-“industrial” biogas plants are per chosen definition “Commercial Biogas Plants or Biogas Plant Systems” with an expected daily biogas production of more than $50m^3$, or 300kWh/d thermal production capacity, or about 100kWh/d installed electricity production capacity.[3]

2.2.1 MEDIUM AND LARGE SCALE BIOGAS DEVELOPMENT IN BANGLADESH

Besides household based biogas production, neighbourhood biogas mini grids for cooking, or few bottling of upgraded and compressed biogas (as bio-methane), there is currently no viable alternative for significantly increasing rural access to clean gas for cooking. Transporting natural gas tanks (Compressed Natural Gas (CNG) - bottles) or establishing an extensive rural natural gas network are both prohibitively expensive (Torn, 2010), and as in 20 years the natural gas reserves from Bangladesh are estimated to be depleted, the use of CNG is limited promoted for new applications. Although 4 percent (compared to 0.3 percent in 2004) of all Bangladesh household are now using mainly bottled LPG (Totalgaz, 2012), and LPG is widely available in urban and peri-urban markets, it has largely failed to reach rural households (World Bank, 2010). There is still few access to bottled LPG in remote rural areas.

Biogas-based power generation was unknown in Bangladesh until 2002. At present, reports (JICA, 2014) refer to about 300 biogas-to-electricity plants in a capacity size of $5m^3$ and more expected daily gas production with installed GENSET engine capacities between $2kW_{el}$ to $260kW_{el}$. Different international development and financing agencies such as BRAC, the World Bank, International Finance

[3] Based on the assumption that $1m^3$ biogas has $6kWh/m^3$ thermal energy and could produce $2kWh/m^3$ electricity. Depending of the efficiency performance (defined in m^3 biogas per day/m^3 fermenter volume), the required construction volume would range from 50m3 (based on $1.0m^3/m^3$) to $250m^3$ (based on $0.2m^3/m^3$), in Bangladesh usually defined with $100\text{-}125m^3$ (based on 0.4-0.5m3/m3).

Cooperation (IFC), Kreditanstalt fuer Wiederaufbau (KfW, Germany), USAID, Asian Development Bank (ADB), and Japanese International Cooperation Agency (JICA), and GIZ are promoting also larger scale industrial biogas plants, including the use of compressed biomethane as vehicle fuel. The largest agro-industrial biogas plant (Completely Stirred Tank Reactor (CSTR) – type) in the country is described to have a capacity to generate over 2700m^3 raw biogas per day. Two biogas-to-biomethane upgrading pilot plants (designed and built by RDA and Khokon Das) have been identified as in operation although still operated as Research & Development plants with varying success by RDA and by Khokon Das; others 4 biogas-to-biomethane upgrading pilot plants are in planning stage.

Since 2006, it is said that about 2,000 biogas plants, having a gas production capacity of at least 5-6m^3 per day, have been built, but data base conditions on their real operational lifetime are very weak. Any biogas digester in Bangladesh able to be counted within these minimum biogas plant sizes is generally categorized as "commercial", but no national agreement about the definition "commercial" has been reached until now within the sector. In addition, since there are many actors as service providers and there is no biogas sector coordination in Bangladesh so far, the exact numbers of biogas plants build larger than the mainly subsidised household sizes, cannot be confirmed.

Establishment of biogas based electricity plants in poultry farms reduces dependency on fossil fuel used for running captive generators. This also ensures bio-security and proper litter management in these farms. Moreover, slurry produced in the digesters as by-product is a good bio-fertilizer. According to the Bangladesh Bureau of Statistics (BBS, 2010), there are more than commercial 70,000 poultry farms in Bangladesh with about 1,700 farms having more than 10,000 birds. Bangladesh therefore has good potential for biogas based electricity projects in poultry farms. IDCOL has so far (July 2016) financed and completed 7 poultry farm biogas-based power plants and one on plant on a dairy farm. But IDCOL alone has an overall target to finance 450 such projects with an average of 50kW installed electrical power capacity. (Source: http://idcol.org/home/other_re) IDCOL also has already a short term financial capacity target to finance 130 agro-industrial biogas-based power generation plants by 2018 (Source: http://idcol.org/home/notice, published October 2015).

Referring to agro-industrial commercial biogas plants (medium and large size) for electricity generation, several organizations and companies are interested in, and have installed systems with varying success in poultry and dairy farms to supply electricity to these farms. Other applications, such as biogas from faecal sludge or sorted municipal organic waste, are not well disseminated yet (beside some pilot plants), although the potential to construct and operate successfully such large-scale biogas plants is available in the international market and could be accessed in case of interest on behalf of the Bangladesh biogas sector.

GIZ under SED program informed that they have installed about 1500 mainly commercial agro-industrial biogas digesters, including plants with 4.8m^3 daily gas production capacity, throughout the country. In 2011 to 2015, RDA, Bogra has constructed 36 commercial biogas plants with a view to supplying compressed upgraded bio-methane (CBG = compressed biogas) and generation of electricity. In summary, more than 228 bigger agro industrial biogas plant systems were installed so far by different organizations, companies, and NGOs throughout the country. These biogas systems often consist of several smaller biogas digesters, which, if operated as stand-alone plant, would not accomplish the given criteria of “agro-industrial” or “commercial” biogas plant. If counted as individual digester, the total number could probably amount to about 2000 biogas plants. To date, the largest biogas plant system with a gas production capacity of 2700 m^3 is installed in Paragon Poultry Farm at Sreepur, Gazipur.

Denmark supports sustainable energy development in Bangladesh through the new Climate Change Adaptation and Mitigation Programme (CCAMP). CCAMP is a two-year programme (July 2014 to June 2016) and has been designed based upon lessons learned from the Climate Change Adaptation Pilot Project 2013-14, and as part of the preparation for Denmark’s planned support to a Climate Resilient and Sustainable Energy Programme 2016-2021. The Programme is focused on climate change adaptation as well as on mitigation issues.

The adaptation part focuses on the construction of climate resilient rural infrastructure in the Southern part of Bangladesh. The mitigation part will promote waste-to-energy from poultry manure and raise awareness on energy efficiency, to stimulate the market for energy efficiency in industries. This engagement is implemented by the International Finance Corporation and will promote waste-to-energy in poultry and large dairy farms throughout the country by applying successes from previous experience. In addition, the engagement will reach out to service providers and financial sector stakeholders to explore and develop partnership opportunities. A knowledge hub on waste-to-energy and handling/enhancement of organic fertilizer from biogas slurry, including technology transfer was established in a partnership between Bangladesh Agricultural University (BAU) and Aarhus University, supported by DANIDA and IFC.

"Organizing livestock farmers into manure management groups, with functional access to (centralized) biogas digesters, technological interventions for purification, upgrading and compression of (biogas to) biomethane, value addition processing of solid and liquid manure into organic fertilizer or soil conditioners and/or organic pesticides, forward linkages of private sector for marketing of manure and manure products, their quality standards and regulations, and government certification systems" will be ensured by the drafted National Integrated Livestock Manure Management Policy, published in December 2015 by the Bangladesh Ministry of Fishery and Livestock. Once in place, this will definitively create an enabling policy support for agro-industrial biogas power loan schemes in getting more demand and access to community owned or operated biogas power projects.

Until December 31 2015, 138 sites of biogas-to-electricity plant systems with gas production capacity beyond the above described household size definition were identified as physically existing. These plants were installed in Bangladesh through different governmental agencies, NGOs and companies. The initial information included:

- 2 large scale biogas plants for poultry litter treated in a CSTR digester as modern tank technology, installed by Chicks & Feeds Ltd., with technology support from HEEEC China with 1350m^3 and 2700m^3 daily biogas production capacity, respectively, in two locations;
- 41 biogas plants built by Seed Bangla in poultry farms for captive power generation with a daily gas production capacity ranging from 250m^3 to 500m^3
- 70 biogas plants (as published by BBDF in October 2015) for poultry litter or cattle manure, constructed by Masum Biogas Engineering with daily gas production capacities between 150m^3 to 250m^3

- 14 biogas plants made under community approach from cattle/poultry/human waste by Rahman Renewable Energies
- 36 biogas plants made under community approach form cattle waste by RDA, Bogra with daily gas production capacity of 60 m^3 each

Through literature, database, and newspaper based investigation and in interviews with Service Providers the study team established until February 8, 2016 a list with 328 individual agro-industrial biogas plants. Ongoing investigations until March 31, 2016 resulted in finally 228 identifiable bigger or equal as the $6m^3$ - expected daily biogas production - agro-industrial biogas plant systems from $6m^3$ to $2700m^3$ expected daily biogas volume. The different numbers are caused by the fact that circulating lists counted each biogas digester as an individual project, although on some farms and locations up to 7 biogas digesters were constructed and the biogas they are producing is used for the same purpose, either in one GENSET, in a joint group of GENSETs, or in the same gas mini grid systems for household biogas cooking stoves.

Although many surveys have been conducted regularly to assess the performance of household biogas plants in Bangladesh (refer to the references below), an independent survey on agro-industrial biogas systems in the country was still missing. With the present study, this gap has been closed. However, the results are discouraging for the applied medium size fixed dome technology, because this design is only based on the enlargement of the household biogas plant model. It is therefore already here in this early chapter recommended to update the knowledge of biogas plant designers and engineers in Bangladesh, to avoid the total break-down of the sector.

Through investigation in literature and donor and financial service provider databases the study team established until February 8, 2016, a list of 228 bigger agro-industrial biogas digesters. The following map displays their geographical distribution:

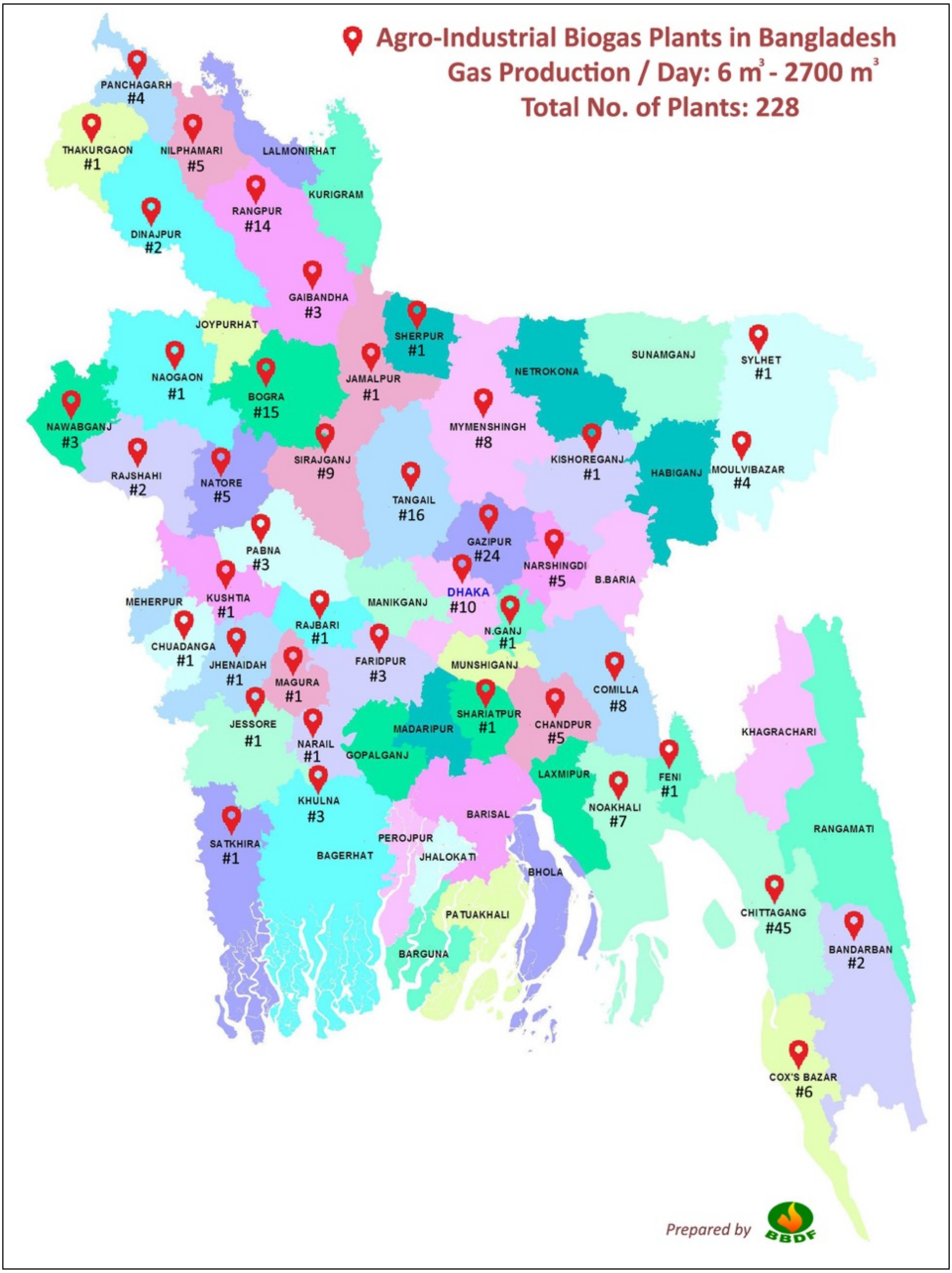


FIGURE 2: AGRO-INDUSTRIAL BIOGAS SYSTEMS ACROSS THE COUNTRY

While investigations until March 23, 2016, resulted in 339 individual digesters, the final list was reduced to 228 agro-industrial biogas systems, with EDGP of at least 6m^3 expected daily biogas volume. The difference resulted from the fact that most of the agro-industrial biogas systems consist of several digesters, which deliver the biogas to the same end use, but they were counted as individual biogas plants. These 228 biogas systems are distributed throughout the country in the following districts:

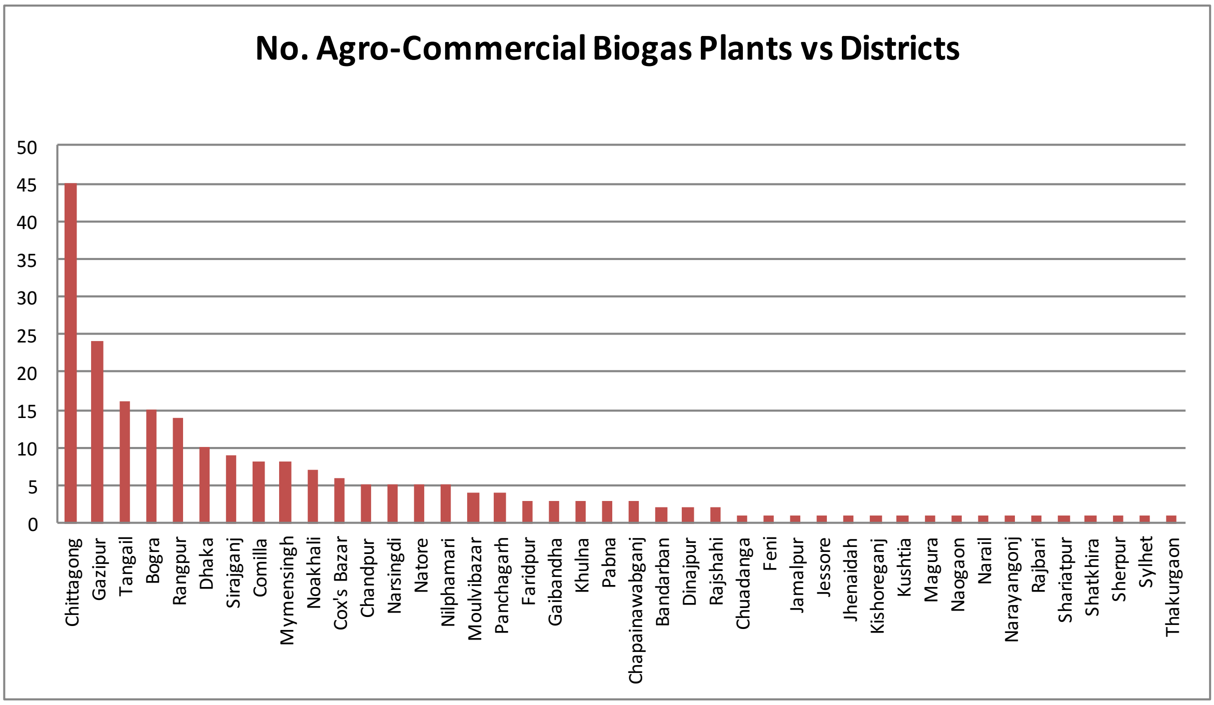


Figure 3: Agro-industrial biogas systems per district

This list again was reduced to the above mentioned 130 biogas systems, as the present study undertook an performance analysis only with medium and large scale biogas plants of at least 50m^3 biogas production per day (volumes of 100+ m3 based on Bangladesh's biogas experts definition of 40 litre biogas per day per kg of fresh cow dung and 70 litre per kg fresh poultry dropping under 45 days hydraulic retention time (HRT) with dung/water ratio of 1:1 (cattle) – 1:2 (poultry)) in order to come up with a comparable benchmark analysis framework.

2.2.2 MEDIUM AND LARGE SCALE LIVESTOCK BASED BIOGAS POTENTIAL

Bangladesh has a huge theoretical potential only for intensive livestock farm agro-industrial biogas production, estimated at about 130,000 biogas plant systems of bigger sizes:

- The Bangladesh Bureau of Statistics reports shown that about 60,000 commercial cattle farms, and

- 70,000 commercial poultry farms. 72,9% of the total commercial chicken production in Bangladesh is in the divisions of the country’s two largest cities Chittagong and Dhaka (FAO, 2008). According to the data provided by the Bangladesh Poultry Industries Association it can be estimated that about 33% of the eggs in Bangladesh come from commercial farm system and 67% from the backyard system.

The Agricultural Sector Strategy from the 7th Five Year Plan (2016 to 2020) for the development of the livestock sector, given attention to the following issues:

- Quality of inputs such as animal feed, day old chicks need to be ensured. Farmers’ skill needs to be developed for moving beyond backyard poultry into small scale commercial/semi commercial production. Easy access to credit is a critical factor in this context.
- Cost management – practical issues related to improving productivity, using cost effective treatments, minimizing post-production losses would all be needed to boost the development of the sector.
- Sustainability –the livestock sector is regarded as one with very high environmental impact due to solid, liquid and gas wastes produced. In Bangladesh, there is experience with biogas technology which, given almost all organized livestock keeping is based on housed animals (a prerequisite for biogas), could be scaled up more widely.

It is estimated by SREDA that if only 10% of the medium and larger dairy and poultry farms would be included in an advanced biogas technology program, they would have the technical potential to generate with 50 MW capacity electricity. However, the technology adaptation rate is currently very slow. Less than 1% of the theoretical market has been addressed so far by currently 14 Bangladesh technology service providers. For details about these enterprises, refer to Chapter 4.

2.3 ENERGY SUPPLY AND SUSTAINABLE DEVELOPMENT

Bangladesh, aspiring to become a middle-income country by 2021, should raise gradually the national energy production to meet the country’s increasing demand. Natural gas, the only indigenous energy source shall not be able to meet that energy ambition. The resource is also not unlimited and the national economy is already experiencing shortfalls in supply compared to the existing demand. Therefore, exploiting the full potential of alternative energies is one avenue towards the long-term energy security.

Energy is one of the basic factors required to alleviate poverty and promote sustainable socio-economic development. There is an acute shortage of both conventional and traditional fuels. To meet the demand of cooking fuels, people are increasingly using cattle dung, agricultural residues, and leaves; thus, depriving the soil of its natural fertilizer. Moreover, a huge quantity of greenhouse gases (GHG) such as CO_2 and CH_4 are emitted every day from open dumping and uncontrolled landfill sites of municipal wastes, but also from poultry litter and some from cattle dung. GHG emissions are responsible for climate change and hence global warming. Bangladesh is considered as extremely vulnerable to the impacts of climate change, such as heavy storms and rains resulting in floods and destruction of assets and harvests; thus, causing even more poverty.

Considering this context, biogas technology can play an important role as alternative and renewable source of energy not only for cooking and lighting of households, but also for large scale generation of electricity and gas for productive use, and to mitigate, even reduce GHG emissions. In the best case, anaerobic digestion or biogas technology helps to conserve traditional biomass fuels, to prevent soil erosion and to increase soil fertility, as well as to alleviate national budgets from costly imports of fossil fuels and mineral fertilizer. Bangladesh is in a very favourable position for biogas production regarding the availability of raw materials and year-around climate conditions.

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3. MARKET POTENTIAL AND POTENTIAL MARKETS

The first International Renewable Energy Conference was held in Bonn, Germany, in 2004 and a global platform named REN 21 was established. As a follow-up Beijing International Renewable Energy Conference was held in 2005, Washington International Renewable Energy Conference was held in 2008, Delhi International Renewable Energy Conference was held in 2010, Abu Dhabi International Renewable Energy Conference was held in 2012, South Africa International Renewable Energy Conference was held in 2015. As an impact of these initiatives by the global leaders, about 150 countries now have their renewable energy policy. Global renewable energy capacity now crossed 400GW and is progressing at an accelerated rate. In the field of biogas, some countries could show notable success. China installed about 40 million plants, India could construct about 5 million, European countries generating about 14,000 MW power from biogas.

Bangladesh is one of the low energy consuming countries of the world. At present the annual per capita energy consumption is around 321 kg of Oil Equivalent, including an annual per capita electrical energy consumption from 371 kWh in 2015. With the lapse of time, the national energy reserves are exhausting, but energy demands are increasing. Out of 26 gas fields discovered since 1955, 2 are abandoned, 5 are exhausted and the remaining 19 gas fields are going to be finished soon. Only 8% of the population are enjoying piped natural gas and 62% could so far be covered with national grid. In the rural, where 70% people live, gas dream and permanent electricity supply is scarce. 72% of the country's electricity is natural gas based. It clearly indicates that, the day is not too far, when there will be no gas in the country. Searching renewable sources of energy is the only option to meet the situation.

Bangladesh has favourable climate for most of the renewable including biogas technology. The ideal temperature for biogas in the mesophilic range is around 30 to 40 degree Celcius (^{o}C), and in the psychrophilic range from 15 to 25^{o}C. The average air temperature in Bangladesh usually varies from 15 to 40^{o}C. But the inside temperature of a biogas digester remains 22 ^{o}C to 33^{o}C, which completes for both requirements.

Raw materials for biogas are available across the country. All organic materials that easy decompose and pollutes environment, spreads bad smell and diseases, are the potential raw materials in a biogas plant.

Rearing of poultry and livestock takes place in households and in commercial farms. According to governmental definitions farms are non-financial corporations. The terms smallholder and household or family farm are often used interchangeably or in combination without clear definitions. Lack of clarity regarding terminology as well as the basic composition and diversity of the agricultural sector is a serious barrier to effective policy dialog. As there is no universally agreed definition of family farms, although various stakeholders have established definitions either for purely analytical purposes or for the implementation of government programs. Despite wide variation among definitions of family farms, there are some commonalities. A survey of various definitions of family farms found that the most common aspect of such definitions is the use of family labour and that many of the definitions also specify that the farm is managed principally by the farm owner family.

The livestock sector provides full time employment for 20% of the total population and part-time employment for another 50% of the total population (2011). The poultry meat alone contributes a substantial 37% of the total meat production in Bangladesh (2011). The 2014 from the Bangladesh Bureau of Statistics published national farm poultry and livestock survey covers only privately managed farms. Households and households covered in the Vulnerable Group Development (VGD) programme are excluded from the scope of the present study. This is a government programme aimed at providing micro-credit training and other support to the vulnerable women to start income generating activities. Also, there are two categories of farms: (i) Government dairy farms, (ii) Privately owned and managed farms. The last available statistic survey exclusively covers privately managed farms.

At this point the definition of livestock and poultry farm is important. The following definition is used in the governmental statistic surveys since 2008, and may be a good base definition for commercial biogas activities as well.

A. An enterprise established for business, maintains accounts for income and expenditure, has accommodation [house(s)] for production activities, has a signboard indicating the location of the enterprise and type of activities (cattle or poultry) will be treated as farm.

B. However, if a household has an annex to rear at least 3 cows or 20 goats for business purposes will be treated as farm. Similarly, if a household has an annex to rear at least 50 chicken or 20 to 30 ducks for business will be treated as farm.

C. Household having 5 to 6 cows or bulls for plough the land will **not** be treated as farms. Also, households having 10 to 15 chickens or ducks, as a part of household activity and occasionally sells hens or ducks and eggs will **not** be treated as farms.

The poultry producing areas in Bangladesh having a high accumulation of poultry litter, are mostly occupied by intensive layer farms, in addition to smallholder poultry farms. A set of guidelines for commercial poultry farming is approved by the government, but they do not include yet best manure management practices. Very few poultry farmers having larger anaerobic digestion systems but only biogas production is not enough to make litter management cost effective. Environmental policy distortions, and the lack or poor enforcement of existing guidelines often intensifies pollution problems. Moreover, farmers' and operator's awareness and extension service activities on safe farming and food production, combined with plant safety and operational skills must be strengthened. Direct discharge of livestock manure or slurry into river, pond or any water streams pose a risk for the spreading of pathogens. Nevertheless, aerobic (i.e. composting or aerated lagoons) or anaerobic digestion may help reduction of pathogens and as well as weed seeds in livestock manure. Direct discharge of solid and/or liquid livestock manure into standing waters builds up nutrient contents of water increasing biological oxygen demand (BOD) and endangering the survivability of aquatic structures.

But the supply of insoluble grit to poultry is generally made using such substances as flint, quartz, granite, gravel, or sand. The soluble grit feed to poultry comprise calcium-rich mineral compounds such as limestone, oyster shell, cockle shell, Malton fossils, or rock phosphate. The insoluble grit becomes a large problem when delivered to an anaerobic digester for biogas production. The grit can clog up the feed lines and fill up the internal space of the digester. It tends to be abrasive as well and can easily damage equipment. The insoluble grid is only dissolved during digestion or by pre-heating of the excreta mix with the organic part where it is glued to. On the plant visits it was observed that all the older 100% poultry droppings filled biogas plants are clogged or nearly blocked by limestone contained in the poultry litter[4] and dissolved during anaerobic digestion. It is difficult to empty, and not possible to retain the soluble grit before the digester, only the insoluble grid could be retained by professionally well-designed sand pre-settlers.

3.1 THEORETICAL BIOGAS POTENTIAL

At present, there are about 100,000 small sized biogas plants in the country, most of them are household farm biogas plants in the above governmental statistic surveys defined categories B if poultry, or C if cow or buffalo dung is used.

The data analysis of the market potential become more complicated than expected. The consultants compared different sources to screen the real commercial agro-industrial potential for medium and larger biogas systems in Bangladesh, but received very contradictory information. For example:

1. *Newest FAO statistics from 2014 for Bangladesh are showing 255,311,000 layer and broiler chicken, and 24,988,000 cattle and buffalo (including dairy cows).*
2. *in the commercial statistics of Bangladesh already households with more than 2 cows and more than 5 buffaloes are counted and registered as "farms". This results in an overall potential of 130,000 commercial farms = commercial biogas clients.*
3. *IFC published 2013 that about 4.5 million tons of waste are generated daily by poultry farms, resulting in 2 million tons of GHG emissions and negatively affecting the environment (see attached). Using the FAO figures published with 296,263,000 chicken in Bangladesh. 4,500,000 tons/day / 296,263,000 chicken = 15 kg droppings per bird per day(!)*

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[4] As birds have no teeth they use small bits of grit and stone to grind up their food before they can digest it. Free range poultry may find enough but if they are in a chicken pen or cages, they need extra in the form of poultry grit. Layers also need a supply of soluble calcium in the form of oyster shell or limestone flour. This helps to maintain the strength of the egg shells. There are two main types of grit, each different in function – Insoluble Grit – useful for its mechanical effects in the gizzard, and - Soluble Grit – valuable for the calcium, which it supplies to the hen, after it undergoes solution in the gastric juices. Some feeds may already contain this supplement but if not, and hens lay soft shelled eggs then they should benefit from some extra.

And these sources are cited again and again in different papers about the theoretical biogas potential!

Referring to commercial and agro-industrial biogas systems the overall theoretical potential could be calculated based on the following data on poultry and livestock farms, published by BBS 2008-2014. The theoretical biogas potential is calculated based on the following parameter:

10kg dung/cow/day, 1kg cow dung produces 40l biogas/day

= 0.4m^3 biogas/cow/day (cow definition is based on FAO's Tropical Livestock Unit (TLU) equivalent to 250 kg life weight),

and

0.1kg poultry droppings/bird/day, 1kg poultry litter produces 70l biogas/day

= 0.007m^3 biogas/bird/day (figures are from Grameen Shakti, 2007).

This sums up to 1.8 million m^3 biogas/day: 1.26 million m^3 biogas/day in the poultry sector and 0.54 million m^3 biogas/day in the cattle-buffalo sector (55% are dairy farms, BSS 2010)), this corresponds to daily 10,849 MWh thermal energy,

or to produce daily 2,260 MWh electricity energy with many small generators, with 82MW installed capacity, operating 22 h/d on 80% load.

In 2016, 2.29MW generator capacity were already installed, but only used at 7.3% load factor.

The potential estimation is based on the biogas productivity per feedstock unit used in Grameen Shakti's "Biogas and Organic Fertilizer Guide" from 2007.

TABLE 3: ESTIMATION OF THEORETICAL BIOGAS POTENTIAL

		Per farm (m^3/d)	average farm size (heads)	Total (m^3/d)
No. of dairy farms (total)	**58,081.00**			
No. of dairy farms with more than 50 heads of cattle	2,910.00	67.20	168	195,552
No. of cattle farms with more than 30 to 50 heads of cattle	5,148.00	19.60	49	100,901
No. of cattle farms with 11 to 29 heads of cattle	5,119.00	11.60	29	59,380
No. of cattle farms with 3 to 10 heads of cattle	44,904.00	3.60	9	161,654
No. of Buffalo farms (total)	**1,924.00**	-		
No. of farms with more than 30 buffalos	612.00	32.40	81	19,829
No. of farms with 11 to 29 buffalos	614.00	11.60	29	7,122
No. of farms with 3 to 10 buffalos	698.00	3.60	9	2,513
Potential based on total No. of cattle and buffalos (BBS, 2010)	**60,005.00**	**1,367,129.00**		**546,852**
Total no. of chicken farms	**72,644.00**			**1,261,398**
No. of broilers farms	53,855.00		34,873,000	
No. of layer farms	18,562.00		30,314,240	
No. of hatcheries (BBS, 2010)	227.00		3,867,000	
Farms with 1,000,000 birds and more	2.00	10,500.00	1,500,000	21,000
Farms with 400,000 – 999,999 birds	17.00	6,999.99	999,999	119,000
Farms with 50,000 – 399,999 birds	213.00	2,799.99	399,999	596,399
Farms with 20,000 - 50,000 birds	1,500.00	350.00	50,000	525,000
Farms with 10,000 - 19,999 birds	1,200.00	139.99	19,999	167,992
Farms with 5,000 - 9,999 birds	8,000.00	69.99	9,999	559,944
Farms with 1,000 - 4,999 birds	12,000.00	34.99	4,999	419,916
Farms with 500 - 999 birds	45,000.00	6.99	999	314,685

Sources: BBS 2008 & 2014, and BRAC 2010

The above figures are based on BBS 2008 – 2014 statistics about farms and livestock population.

To include other agricultural wastes such as corn cobs and stovers, grass cuttings, rice husks and unused excess straws, and waste from sugar mills and further food processing industries as potential feedstock for agro-industrial biogas plants, a detailed biomass assessment and related logistic and economic survey is required. However, it is recommended to focus such assessment and feasibility studies only on specific locations where the baseline conditions for agro-industrial biogas systems are obvious. This is under the given conditions usually the case in the neighbourhood of livestock or poultry farms.

Besides cattle dung and poultry litter, there are other agro-based waste which have great market potential for commercial biogas production in Bangladesh. These include;

1. Pressed mud and wastewater from sugar mill
2. Spent wash from distilleries
3. Waste from food processing industries
4. Waste from meat processing industries
5. Corn Cob and Stover
6. Potato plants and other unused agriculture waste
7. Water hyacinths
8. Pulp and paper industries

Sugar mill waste:

According to the South Asian Association for Regional Cooperation (SAARC) seminar reports in 1995 and again in 2004, in Bangladesh from 15 sugar mills about 80,000 tons pressed mud are produced every year from which about 3.2 million m^3 of biogas can be produced, that have a potential of about 5000MWh electricity, produced at least while operating in the crushing season for 150 days.

Distillery waste:

There are four distilleries in Bangladesh. Most of the distilleries are producing alcohol, liquor and other products using molasses as raw materials. Each distillery discharges about 200 tons of spent slurry every day. According to Biogas Research and Training Centre (BRTC) at the Biomass Institute (BIOMA) of the Chinese Ministry of Agriculture in Chengdu, one ton spent slurry can produce about $34.2m^3$ biogas.

Therefore, from four distilleries about 9.9million m^3 biogas can be collected yearly, which can produce 15,200 MWh electricity per year. (*Source: Bangladesh Journal of Science and Technology 2002)*

Pulp and paper industries

The pulp and paper industry has about 35 MW being generated from cogeneration and this is expected A stage-wise cogeneration implementation strategy to increase to more than 50 MW.

Mango waste:

In Bangladesh 40,000 tons of mango waste is available every year. This can produce 4,000,000 m^3 biogas. But no one ever took any initiative to use this huge quantity of biogas. Pran Industry took some initiatives, but with no achievement so far.

Corn stover and cop residues:

In Bangladesh, maize is cultivated in about 300,000 hectares of land. In about 100,000 hectares of land, the farmers cultivate double crop system. Usually, maize produces about 40-50tons of biomass per hectare. After harvesting maize, the excess biomass is of no use. The residual biomass also can be used to produce valuable biogas and electricity.

Although municipal organic waste in not in the scope of the present study it should be mentioned that Bangladesh is a country with 164 million people (December 2016). 34.2 % of the population is densely urban (56,856,665 people in 2016) and generates about 25,000 tons of waste every day. According to JICA's studies from 2012, 75% of these waste is organic, which is suitable for biogas production.

4. Sample Plant Visits

Until End March 2016, the study team visited a total of 30 agro-industrial biogas systems across the country. The following selection criteria were agreed before with GIZ-SED program:

1. Preferred are agro-industrial plants originally designed to produce electricity or upgraded bio-methane; feedstock should be either poultry droppings or cow dung. In case the study team would come across any sewage or faecal sludge fed biogas plants or municipal or industrial waste-to-energy plants, these should not be considered.
2. Expected daily biogas production of the visited system should be at least $40m^3$ per digester unit
3. Constructions from at least 4 technical service providers
4. About 50% of the visited and analysed plants should have been built and commissioned before 2012
5. Geographical clustering of plants to be visited could be applied as far as possible to buffer travel budget limitations.

The plant performance and appearance as well as the operator’s and owner’s opinion was documented for in-depth analysis and to allow for ‘lessons learned’ before designing a draft road map for market development. To obtain comparable information, a questionnaire and a template for reporting was developed. Detailed findings and conclusions are included in all Chapters, and provide the basis for the entire study.

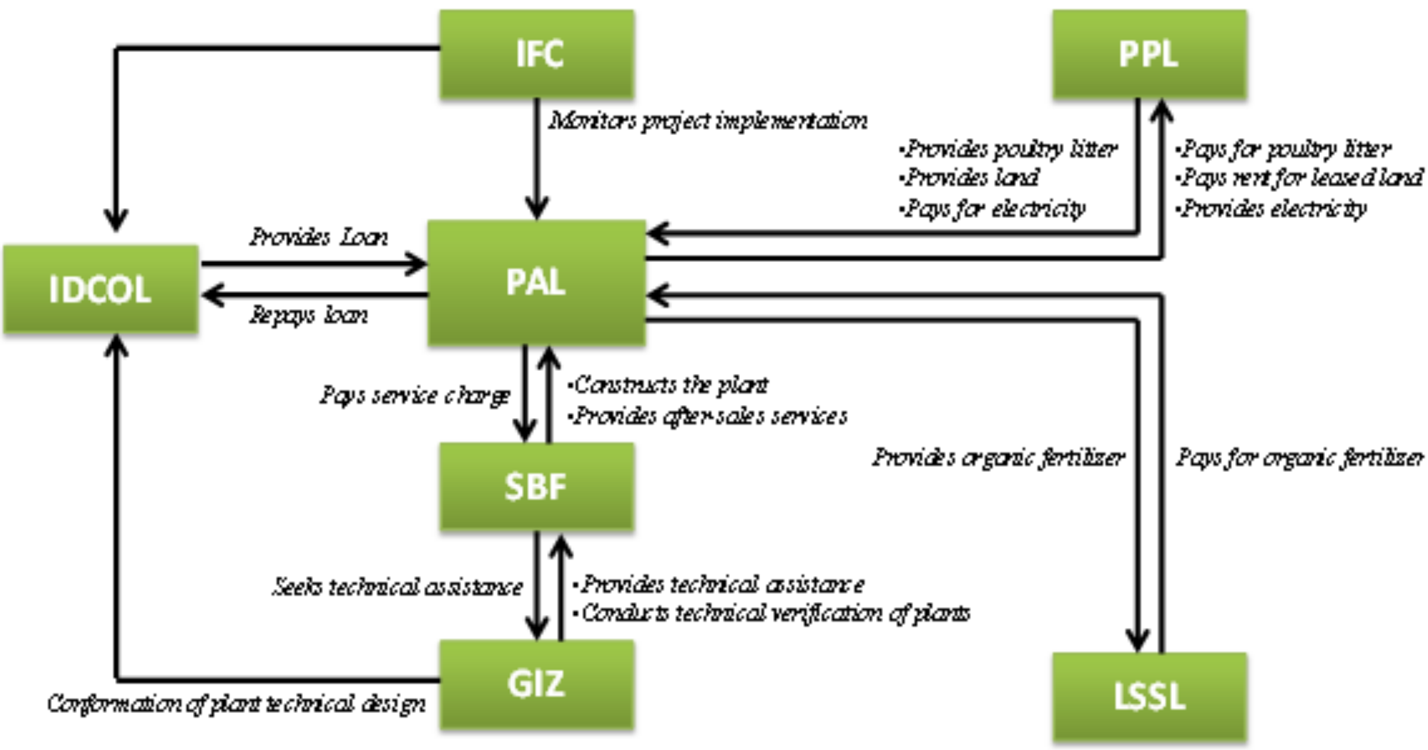
4.1 Case studies on agro-industrial biogas systems - examples for the analysis of agro-industrial biogas value chain

The following case studies have been compiled to showcase the business potential offered by agro-industrial biogas systems already operated in Bangladesh. These examples have been selected although most if not all of them need to be improved for optimum performance, both in biogas and slurry use.

4.1.1 PROJECT: PHENIX POULTRY LIMITED (PPL)

The project site is in Memberbari, Gazipur, in Phenix Poultry Limited ("PPL") in Dhaka Division. The project was envisioned to generate electricity from available poultry litter by the installation of 400kW generator (4 numbers @ 100kw each) and used since 2013 for captive demand of electricity of the firm.

The proposed Project was financed under the cooperation agreement among IDCOL, IFC and GIZ. As per the cooperation agreement, GIZ was responsible to provide technological and technical supports to PPL, assist in selection of Project equipment and machineries and turnkey contractor, if necessary and conduct technical verification during installation, testing and commissioning stages of the Project. The design of the bio-electricity plants was approved by GIZ and developed by Seed Bangla foundation. The envisioned stakeholder as per appraisal report was as of the figure below:



The technical solution provider for the Project is Seed Bangla Foundation (SBF) (SBAL). The project estimated to produce has capacity of producing 2548m^3 of biogas and 9000kg of organic fertilizer per day.

The project was designed for 300000 layers with the estimate budget of 113.66 million BDT (appraisal report). IDCOL supported 55.55 million BDT as loan (source: IDCOL annual report 2013-14)

The given basic design parameter assumption was as follows:

- Droppings from each bird = 120 gram/day
- Addition of 2/3 water to liquefy the substrate and lower the nitrogen content to a level of under 5g/l
- Gas production per kg of dropping =70 litres
- Usable gas = 80% of total production due to self-consumption. 20% must be flared or vented
- Fertilizer production 108 gram /bird/day plus 240 g water = 348 gram/bird/day

Overall Status of the Plant

The firm has 100,000 layer chickens at February 2016. The biogas plant construction was started in 2012 and completed in 2013. First operation test was performed in July 2013. The regular operation of electricity production has started from November 2013. Two generators are running about 8-10 hours per day and the average electricity consumption of the firm is 100kW per hour, however the consumption will be increased in summer. Five digesters were constructed to treat droppings from 10 poultry sheds. 4 digesters are still in operating; one is not in operation as it is fully clogged with limestone sediment, and all emptying trials failed. According to the companies' information the running plants are also already filled up 60% of the fermenter volume with the same sediment. The inspection team observed the non-operational digester, the others could not be visited due to bio-security issue of the farm.

Inlet: The inlets were tried to be kept open after the liquefied litter open channel flow towards the digester opening. Slurry is found deposited in the channel and not passing to the plant. (photo: 2, 3, 4). Sand deposits in the open Channel were removed continuously by hand from the open channels. However, the removal of sand is not sufficient as the sand hangs on to the organic and only falls out during digestion

Bio-Digester: Digesters base is round and constructed with cement brick masonry and a casted reinforced concrete dome. The dome is well seen above the ground. There is no control device installed to check if the given design gas pressure of about 25kPA (2.5 m water column) could be maintained. Additionally, there is a big chance that mini cracks may occur in the brick and cement mixture, as a bigger part of the dome surface is not covered adequately with soil as counter pressure material.

Hydraulic Chamber: Rectangular hydraulic chamber is constructed adjoining to the digester. The displacement tanks are covered with heavy concrete slabs; slurry is spliced around the hydraulic chamber and in all surrounding. Through the heavy sedimentation of sand from the chicken litter these chambers are almost filled and cannot be used as liquid compensation storage for the internal stored biogas.

Biogas Storage: Four extra biogas storage balloon of red mud composite material are installed to balance the production and consumption of biogas (photo: 9), Due to the reduced gas production the flexible biogas storages were only filled 1/3 of their capacity.

Slurry management: An additional pond is made at the side of the biogas plants and slurry is pumped to these open shallow pond (see photo: 5, 6 & 8). The pond is not bottom lined, which may cause leakage of organic load (high COD, High BOD) and nutrients into the ground and therefore could pollute the groundwater resources.

Gas Purification/ Sulphur removal: Three iron pellets tower purification unit are setup for the purification of gas (photo 12). The surroundings appeared to be very clean, and it seems that the pellets, necessary for the sulphur removal seemed never have been changed in the lifetime of the plant. There is no sulphur measurement or any gas quantity or quality measurement equipment installed.

Electricity Generation and Distribution: Four 100 kW Chinese Biogas generator from CAMDA http://www.camdagenerator.com are installed. The company's current average electricity capacity demand is around 100kW and two generators are operated at once. Per feasibility report one chicken produce 0.0072 m3 biogas per day as there are 100,000 chickens at present, and has potential of producing 720 m^3 gas per day which is equivalent to 1,440kWh (=720m^3 x 2kWh/m^3 biogas (as average efficiency factor for converting biogas to electricity in combustion engines).

According to companies' operational personnel, two generators are operated for 8h per day with an average output of 100kW equivalent to 800kWh, which is nearly same as the theoretical production.

Identification of Project Challenges

- Blockages in the inlet
- Digester filled up with limestone
- Use of too much fresh water for dilution and flashing droppings
- No effluent post treatment
- Disposal and storage of slurry
- Sound pollution
- Gas pipe installation (Very unprofessional, not following Bangladesh's gas standards)

Description of challenges

Litter blocked in the inlet: the manure does not flow easily from the inlet into the digester. The operator has made a lot of effort to push the manure inside the digester through the help of a bamboo stick. According to the workers, it was no problem in the beginning in 2013 and gradually the problem increased becoming severer day by day. At present one of the plants is already totally blocked and no biogas is produced there anymore.

Digester filled up with limestone: It is observed that the plant is filled up with piled up sand and limestone material inside the digester. The plants were well run for two years and at present 60% or above of the plant is filled with hard material, one digester is fully filled up completely. By sedimentation also the digester displacement tanks are filled and generally and up to 60% of the digester volume is lost. This causes a shortening in retention time in the process and a too high organic loading rate of the organic dry matter in the digester.

Disposal of slurry: The slurry was initially assumed to sell as fertilizer and get some revenue form it, but the process as well as the liquid/solid separation technology failed to cope with the concept and effluent disposal is now a big problem. Due to the lowered retention time in the digester, the slurry is not well digested, which could be seen in activity of gas production taking still place in the digestate storage ponds. The depth of the pond as well as the overall volume was not disclosed. Therefore, we could not calculate the storage time neither climate gas emissions from the pond. Due to the high usage of water in the mix 2 parts of Water to 1 part of Chicken droppings a tripling of the volume occurs, resulting in a three times bigger effluent storage capacity than without biogas plant. The initial post treatment through a liquid solid separation by a mechanical screw press did not work as the liquid chicken manure is too high diluted, few coarse material is contained, and the abrasive sand creates mechanical problems.

Sound pollution: the generators are producing a huge sound around the company as the engines are not encapsulated with sound proof covers. Due to the obviously no more functioning sulphur removal the H_2S remaining in the biogas is causing corrosion to the engines. Fortunately, not all the engines are running on full load therefore the need for overhauling was prolonged.

Piping (Very unprofessional): Pipes are not properly aligned and no adequate water traps and drains are place, however the pipes are partly underground from plant to storage bags. Similarly, it is just overhang from storage to generator house.

Impact of challenges

The above-mentioned challenges have several impacts on the biogas system perception and growth of the entire industry, the following points have the most adverse impacts

- Potential pollution of surrounding and ground water
- Retardation of biogas market: no one on the farm staff was found which agreed to build these plants again
- Bio-hazards through spreading of disease through still untreated substrate
- Air pollution from smelly undigested substrate and uncontrolled methane and sulphur emission from digester cracks and open end storage ponds

Proposed immediate solutions

- Immediate cleaning of digesters (with economic analysis) and continual cleaning of open drains and inlet at least once per week
- Improvement of post treatment and storage pond through a HDPE or PVC bottom liner and a gas-tight but re-movable membrane cover
- Regular monitoring of gas production, gas quality and servicing of desulphurisation
- Sound capsuling of CHP

Overall suggestions for further projects

Small and big fixed dome biogas digesters are not the appropriate solution on intensive poultry farms, although they are working for the first 3-6 years. For substrates with a high calcium carbonate and grid sand content, systems with continual sand drain needs to be included in the digester system. As a best solution for chicken droppings a plug flow digester with a continual sand and limestone drain is needs. With continues stirring intervals, sand fall out takes place easily. Through the slow movements of a paddle stirrers a very low wear and tear is possible. In Germany, there are more than 30 years of experience with these systems. Also, thermophile heated gastight pre-hydrolysis tank with 2-3 days' retention time, or in ambient temperature with 5-10 days' retention time can solve the sand separation problem before digestion. It is recommended to heat the main digester to physiological bird body temperature, and with internal submergible or paddle stirring devices the biogas production increase up to 3 times from the same substrate and therefore improves efficiency and limestone separation considerably.

Analyse the problem beforehand was severely not taking place and without an appropriate solution such digester operation will be stopped (in this case nor more feeding is possible). Doing maintenance in time and do not delay implementing these measures. A thorough understanding through training and continual exchange amongst designers and operators must be implemented. Through these measures the project can be properly planned e.g. starting from the end-point of managing the bio-slurry first.

Photographs

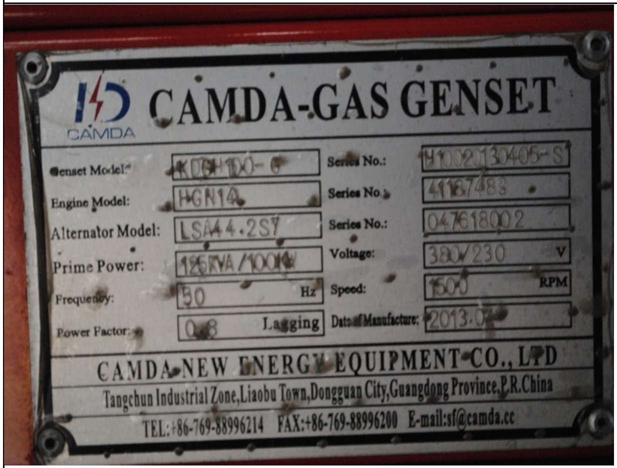


Photo 1: Generator manufactured in 04/ 2013

Photo 2: Litter collection with conveyor belt

Photo 3: Ditch/Channel after collection

Photo 4: Inlet blocked

Photo 5: Sand piling near Inlet

Photo 6: Outlet

Photo 7: Taking electronic measurement

Photo 8: Slurry storage pond

Photo 9: Gas storage balloon

Photo 10: Gas pipe joints/ butt joint

Photo 11: Gas pipe

Photo 12: Generator House

Photo 12: Sulphur removal

Photo 11: Generators

4.1.2 PROJECT: RASHID KRISHI KHAMAR LTD.

Rashid Krishi Khamar Ltd, Poultry Farm situated on 12ha area, includes three layer houses, with the total capacity of 90,000 birds or 30,000 for each unit. In February 2016 two units where occupied with total 60,000 birds. Additionally, five fish pound are located on the farm, with approx. 12,586 m^2 of water bodies for commercial use. The farm also includes a cowshed with around 14 dairy cows and fruit trees for own consumption, alongside with facilities for the employers, including community kitchen.

Initially 7 biogas digesters where operating parallel on the farm, since 2009 as informed per operator, with 70m^3/day expected biogas production for every digester.

Each layer house relates to two digesters that supposed to operate during occupancy of the unit. Expected electricity generation of total 50kW (3 x 18kW) for 8 hours or 400 kWh per day. Each generator of 18kW installed capacity is considered for one unit, with two parallel digesters. Another digester is connected to a cowshed and operating the whole year around.

By the moment of the visit three digesters out of seven where still in operation, two for the poultry and one for cow manure. At the time of the visit, no electricity was generated. As informed by the operator, the electricity production was stopped since end of 2015. Our request to see the generator facility was denied, with the reasoning that the generator is no longer in operation. The reason for the shutting down the generator was not communicated. On the other hand, the reason behind the closure of 4 digesters (2 poultry units) is reported to be blockage from sediments since end of 2015, due very high grid sand and limestone content in the poultry manure and the sediment accumulation inside the digesters. To remove the sediments from the digester it needs to be easy accessible, which is not the case in the dome design. As per operator, the blockage of the remaining two digesters for poultry manure is expected to occur soon. The only digester which is operating obviously without problems that is connected one to the cowshed, and it is operating the whole year (Photo 2). By the moment of the visit three remaining digesters where producing gas, that was utilized together for cooking purpose for about 8 hours per day (Photo 3). The farm was not able to establish a market for bio-slurry, but uses around 30% by itself for own fruit trees plantations. The application of bio-slurry takes place after being air-dried in ponds (Photo 4).

The observed discrepancy from the project planning and the implementation are:

1 Proposed digester design was a so called Up-flow Anaerobic Sludge Blanket (USAB) with expected daily biogas volume of 400m^3, instead 7 underground fix-dome digesters which were finally implemented with gas capacity of 70m^3 each or 490m^3 all over. The change of the design had an impact on the assumption about the project. The project proposal assumed that 90% of the organic matters will be converted into biogas by the high rate UASB digester,

however for the given fixed dome digester removal rates are less than 90% also usually it may vary from 35-70% under mesophilic conditions. Therefore, the amount of remaining sludge generated is much higher than it was initially assumed.

2 Project plan assumed the daily production of substrate around is 3t per day and unit of 30,000 layers. or 100 g/d per chicken for biogas production (Page 7) and later it was calculated with 66 g per chicken for the generation of slurry (Page 10). However, per estimation of the operator, each bird produces around 18kg of manure during one production cycle of 16 month (18kg / 16 month / 30 days), that results in 37.5 g/d per chicken. Since the biogas quantity is not measured, different values are leading to different assumption about expected biogas quantity.

3 Estimated amount of bio-slurry contains errors in the calculation; hence it was assumed that also the dilution water will be depredated by digestion process, which is not the case. Therefore, the amount of bio-slurry is higher than it was first estimated. Because generation of methane occurs only from the organic dry matter content of the substrate.

4 Revenues that the project should generate, based on initial assumption of the project plan, do not meet the reality, therefore the Net Present Value needs to be adjusted. Hence the conditions for revenues are not met by the project. Initial forecast was based on hypothesis that the operator would be able to sell liquid bio-fertilizer with 25% of the amount in the 1st year, 75% in 2nd and for the following 8 years even the whole remaining amount, for price of 1 BDT/kg. In the reality, it was not possible to find a sales market for the bio-slurry. The operator mentioned these is because of regulations that restrict sell of self-produced organic fertilizers in Bangladesh.

4.1 Assumption about revenues from electricity generation differing from the current state of the project, hence the generation of electricity is being stopped. Also, the fact that the electricity production is not measured by electricity meter, makes identifying of generated revenues from diesel and electricity saving a difficult task.

4.2 Generated revenues from cooking gas saving where not considered in project planning stage.

5 The initial goals described by the project plan could not been achieved by the project.

5.1 Promote usage of biogas based power generation technology in Bangladesh.

Since 2 out of 6 digesters are working and 4 digesters are reported to be blocked, due very high sediment concentration, and the remaining two digesters facing the same problem soon. As these challenges are well known in the poultry scene, one cannot recommend such designs for further promotion of biogas on poultry farms.

5.2 Earn reasonable revenue streams from the investment in the long run.

It seems that the expected revenues couldn't be generated in terms of bio fertilizer and only partly for electricity generation. Therefore, calculation is needed to be adjust the investment plan according to the given situation.

5.3 Make the environment safer.

It seems that the concept does not reduces stress on the environment for three reasons. (1) First, the constant methane leakage from the open slurry pond and from the digester inlet tank where observed. In the context of the global warming potential of methane is considerate to be 21 higher than CO_2, hence this can cause negative impact on the environment. (2) Additionally, the drying beds for slurry are not bottom lined or back drained, and may contaminate groundwater. (3) A fresh water consumption for diluting and flushing does not reduce impact on the environment and even increasing the waste volume to manage.

6 Identification of Project Challenges

- Blockage of four digesters and stop of their operation.
- No electricity generation, reasons where not communicated.
- Sludge generation and management challenges.
- Methane leakages (Photo 5).
- Improperly installed gas distribution pipes (Photo 6).

Description of challenges

1. The main challenge of the project is blockage of 4 digesters, and rapid filling of the remaining two, caused by accumulation of sand and limestone contained in poultry droppings. This is a very common problem and need specific consideration in design of the digester and the process. Hence a significant amount of waste cannot be treated and so 30,000 birds producing about 90t of waste per month without adequate waste management system. For the empting of the digester there is no easy accessibility. And if an access can be created, the empting of these contents from such a digesters design could only be done by human labour, that is a very dangerous task and need special safety measures.
2. No electricity production, for unknown reasons.
3. Due the dilution of the substrate with fresh water (Photo 7), in ratio of 2 (Water) :1 (Droppings), the biogas production increases the pollution instead of reduction. For example, 30,000 birds producing 3t of manure per day, the amount of effluent increases up to approx. 9t. This bio-slurry is collected before it is discharged to unlined lagoons and for air-drying. As per operator 30% of the bio-slurry is applied at the own farm for fruits trees, no market for the organic fertilizer could be established, may due to restrictive regulations in Bangladesh.
4. Permanent emission of remaining biogas potential was being observed on the surface of slurry ponds and inlet tank.
5. To the ground hanging biogas distribution hoses may cause condense water blockage of the biogas flow.

Impact of challenges

1. On the one hand, digester is not operating and causing the lack of opportunity to produce biogas, potentially up to 216m^3 daily per digester unit. On the other hand, the generated waste remains without adequate waste management and therefore 6t/d remains untreated. to global warming, with global warming potential 21 times higher than CO_2. The economic impact is that the estimated revenues will be not generated and this affects the economic feasibility of the project, which might be no longer economically feasible under the given circumstances.
2. The lack of electricity generation, may cause higher diesel consumption of the back-up generator, consequently more GHG emissions and increase fossil

fuel expenditures. Return revenues from electricity generation are not realized, that affects the economically feasibility of the given project.

3. Increasing amount of effluent to be manged after the digestion process are caused by the dilution with fresh water. It can be claimed that daily 6t or $6m^3$ of valuable fresh water per unit is been polluted with the current process design of these dome biogas plants. More bio-slurry is being generated, but that it was assumed by the project plan. But as there is no market for the liquid fertilizer, the assumptions about the revenues could not been realized, with another significant impact on economic feasibility of the project. Additionally, the drying ponds are not lined tight and may result in groundwater pollution.
4. Methane emissions creates loss of biogas that can be utilized, at the same time causing GHG emission, which is contributing to global warming.
5. Hanging gas distribution pipes can block the pipe with condensed water and able to disturb the gas flow.

7 Proposed solutions

1 If the present operator side planned steps to empty the blocked digesters (soak the digester with fresh water and pumping out) doesn't show any effect, creating the accessibility with new side openings could be an affordable solution to remove the sediments out of the digester. However, high safety standards need to be ensured by performing this task. Measures like external oxygen supply must be provided, additional to personal protection clothing.

1.1 Redesign of digesters, hence enough space is available, another and more suitable type of digester could be the implementation of plug flow covered lagoon digester, or up-ground built CSTR digesters.

1.2 To reduce the use of fresh water and the related pollution, theses process water can be re-circulated. For this purpose, after post sedimentation, the drained water should flow to constructed wetlands. This could be used to remove nutrients for the denitrification of the process water. The high concentration of nitrogen in the digester accumulates in form of ammonia, leads to high pH value of 8.5, which are toxic for methanogenic bacteria. Also, the amount of the slurry for further treatment in the drying ponds would be reduced.

1.3 Additionally, use of fresh water could be reduced by applying of carbon reach materials as co-substrates into digestion process, for example rice straw. The carbon will control the nitrogen concentration inside the digester. In the current design that nitrogen dilution occurs by dilution with fresh water. Hence the C/N ratio of poultry manure is 10 and otherwise rising pH values will disturb the digestion process. The optimal ratio of C/N for anaerobic process is at 20-30.

2 For increasing the performance of drying ponds, an “structured systematic drying bed structure” could be implemented. The approach would increase the performance and help to reduce already accumulated sludge inside the ponds, at the same time increasing the accessibility of the dry organic materials for its application.

3 Underground installation of biogas distribution piping system.

Overall suggestions for further projects

1. Redesign current concept of the biogas plant for poultry farms. Digester should be, above the ground for easier accessibility, lagoon digester or dry fermentation can be tested.
2. Mixing of carbon reach co-substrate, to avoid high dilution with water and increase sustainable biogas production.
3. Accumulation of sludge inside the drying ponds can be managed by increasing the performance of the system.
4. The process water should pass a denitrification step before being re-circulated. However, an additional treatment of water is necessary due high content of nitrogen, for example with constructed wetland.
5. The gas distribution pipes should be installed in the way that no blockage due condense water can occur.
6. Installation of measuring devices for gas and electricity, for adequate monitoring of the projects should be part the project.
7. Slurry management should be organized.

Photographs

Photo 1: Biogas Plant Unit for Poultry

Photo 2: Biogas Plant for Cow Manure

Photo 3: Biogas Stove

Photo 4: Slurry Drying Ponds

Photo 5: Methane Leakage

Photo 6: Distribution Pipes

Photo 7: Fresh water for poultry dropping dilution

4.1.3 PROJECT: PARAGON AGRO LTD

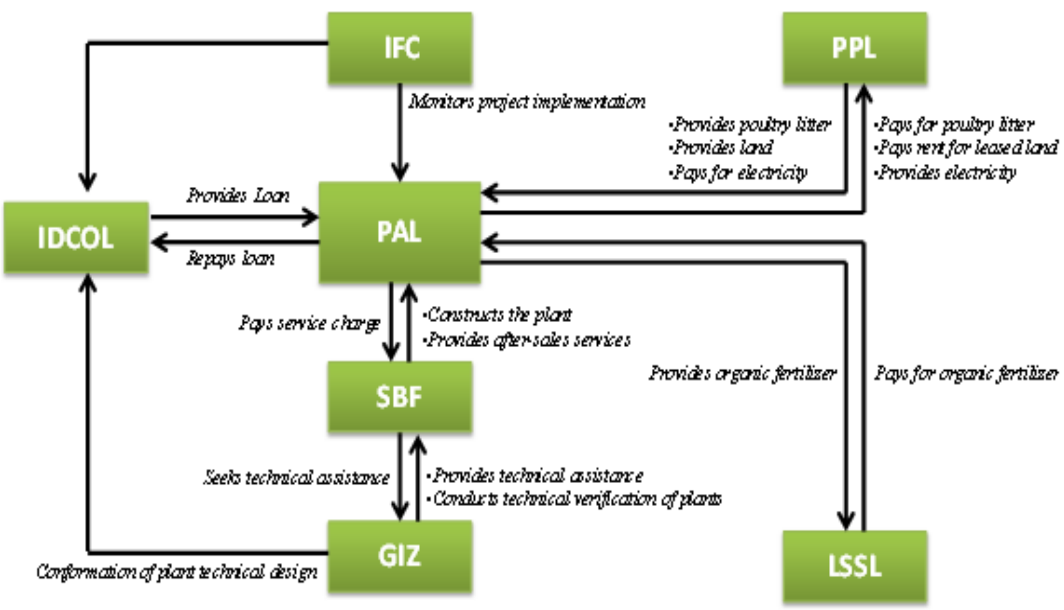
Size:	Two Completely Stirred Tank Reactor (CSTR) digesters, each with 1350m^3 expected daily biogas production capacity
Owner:	Paragon Agro Ltd
Address:	Memberbari, Gazipur
Contact Person:	Mr. Shahin Sarwar; phone: 0171526642
Service Providers:	i) Design, engineering and supply: HEEEC, China ii) Turnkey Operator: Chicks & Feeds Ltd., Bangladesh

Paragon Agro Ltd. is one of the leading breeder farms in Bangladesh. In this facility, there are about 350,000 breeder birds in 9 fully automated housing systems.

The project's objectives were

- Generation electricity from biogas
- Production and application of bio fertilizer in his own land

The project was designed for 350,000 breeders with an estimated budget of 150 million BDT. It was financed by Paragon Agro Ltd (50 million BDT) and by BRAC Bank (100 million BDT). HEEEC and Chicks & Feeds supplied design, supply, installation, commissioning and trial run until gas production including H_2S and H_2O humidity removal. The generator was supplied by the Chinese Jinan Diesel Engine Company (JDEC) with a capacity of 260kW. The project was estimated to produce daily 2700m^3 biogas and 5130 kW electricity per day.



The basic design parameter assumption are as follows:

- Droppings from each breeding bird = 170 g/day
- Addition of water in a ratio of 1:2 to liquefy the substrate and lower the TS of manure

Overall Status of the Plant:

The plant construction started in January 2011, and commissioning happened in January 2012. The farm has 350,000 breeders at present. Average consumption of biogas is 5,250 m^3/day.

The digesters were constructed to utilize litter from the multi-storeyed poultry sheds. Litter plus water is directly drained into the digesters. Sand and sediments are taken out manually from the digesters at an interval of 3 years.

The digesters are round and constructed with steel above the ground. There should be a device to control the given maximum design gas pressure.

Technology: CSTR technology is applied.

Anaerobic Fermentation Process Completely Stirred Tank Reactor (CSTR) is suitable for high concentration fermentation process. The total solid (TS) concentration of input can be 8-12%, and central agitator is installed on the roof of digester to mix the substrate and ensure the consistency of temperature in the digester. Heating and insulation system are also adopted in CSTR process, we use coiled pipe around the outside wall of digester for heating, and usually the heat is from the generator or boiler. High density plastic extruded board is used for insulation system. The temperature in the digester is 38^{O}C. Comparing to other process, CSTR is easy to manage and start-up, besides, the operating cost is low. It has been widely used in Europe and other developed countries. The mixer distributes the feedstock and brings it in contact with the anaerobic bacteria, which is helpful for improving the biogas yield.

Biogas Storage: biogas is stored within the above portion of the digesters.

Gas use: Gas is completely used for electricity generation. The piping system is installed according to international standards.

Biogas Purification & Storage Bio-desulphurization: the content of H_2S can be reduced to less than 200 ppm, and the desulphurization efficiency is 95%, the operating cost is low. Other biogas composition is not measured. The main advantages of this system are

✧ Low operating cost;

✧ High removal rate;

✧ Strong ability of the resistance to load impact;

✧ Easy to start-up, short time;

✧ Simple automatic control system, easy to operate.

Challenges:

- Use of too much fresh water: up to 2/3 of the total feeding volume
- Slurry management

Economic analysis:

The economic analysis could only be based on data provided voluntarily by the operator. It is therefore limited to key data, which could not be verified by the study team.

- Economic benefit from electricity for consumption per day:
  5130 kW x 6.74 BDT/kWh = 34,576 BDT as replaced from the grid (no measuring device installed, only - as usual, data provided by the operator)
- Expenditures: salary of a supervisor per day: 600 BDT
- Net benefits (w/o operational costs) from production of electricity per day: 33,976 BDT
- Net benefits from production of electricity per year: 33,976 x 365= 12,401,240 BDT
- More profit could be made if slurry marketing would be undertaken.

4.1.4 PROJECT: RDA COMMUNITY BIOGAS PLANTS

Size:	Three fixed dome digesters, each for $60m^3$ expected daily biogas production; total expected gas production 180 m^3/day
Owner:	RDA
Address:	RDA Farm, Bogra
Contact Person:	Mr. Samir Kumar
Service Providers:	RDA

The RDA community biogas system is connected to two-storied cattle shed, where 110 improved cows are kept. As per proposal of the project, more cow dung is collected from the cows kept in small farms in the community.

The objectives of the project are

- Generation of electricity from biogas
- Experimenting technologies for bottling Compressed Biogas Methane and for fuelling vehicles
- Production and marketing of bio-fertilizer

The project is designed for 300 improved breed cows. The budget amounts to 4,350,000 BDT, financed by the Government of Bangladesh (GoB). The biogas-to-power plant was designed and constructed by RDA. The expected daily gas production capacity is $180m^3$, and it is estimated that 400kg/day of sundried organic fertilizer are produced.

The basic design parameter assumption are as follows:

- Dung from each cow: 10 kg/day
- Addition of water in a ratio of 1:1 to liquefy the substrate and lower the Total Solid (TS) of manure (8.5%)
- Assumed gas production per kg of cow dung: 0.037 m^3
- Gas consumption: Currently, only $60m^3$/day are produced and used entirely for electricity production for the community. It is planned to use $100m^3$/day for upgrading to Compressed Biogas Methane (CBG) for vehicle fuel.
- Sun/ air - dried fertilizer production: 2.2 kg /cow /day.

Overall Status of the Plant:

The plant construction started in January 2012 and was completed in April 2012. First operation test was performed in May 2012. The regular operation started on June 2012. As the system is only partially in operation, the estimated average production and consumption of biogas is only $60m^3$/day instead of the expected $180m^3$/day. As in any other biogas plant and biogas system in Bangladesh, no measuring devices are installed, and the operator can only estimate the daily gas production. Nevertheless, as only 1 of 3 digesters is operated, the estimated $60m^3$/day could be the maximum amount of biogas produced per day.

RDA has already technical equipment for the CBG station in place with the following arrangements:

- Gas filling capacity: 100 m^3/day
- Compressed Biomethane Gas (CBG) storage capacity: 400 m^3
- Biogas transport capacity: $200m^3$ (cistern on truck)

Total investment cost for the (CBG) station: BDT 85,000,000.00

According to RDA, economic analysis resulted in BDT 47.00 CBG generation cost per m^3. Currently the CBG station is run as experiment with up to 85% to 90% Biomethane content and not yet on commercial basis.

The RDA project indicates that commercially successful implementation of agro-industrial biogas is possible, if the multiple benefits of anaerobic digestion technology are realized all together. This includes:

- Permanent gas production up to the expected amount
- Permanent electricity production and favourable feed-in-grid tariffs
- Permanent bio-fertilizer production by applying natural sun-drying
- Successful marketing of bio-fertilizer
- Upgrading of biogas for bottling Compressed Biomethane Gas (CBG)
- Operating a filling station for CBG fuel for vehicles.

As soon as all the above-mentioned conditions would be fulfilled the potential daily balance between expenditures and income, the owner expects the economic results to be as follows:

Activity	Expected daily amount	BDT/unit	BDT/activity/day	BDT total/day
Selling of CBG (storage capacity)	400 m^3	35.00 (usual selling price for CNG/m3)	14,000.00	
Selling of Bio fertilizer (if!)	2,700 m3	5.00	16,000.00	
			TOTAL INCOME	30,000.00
Purchase of raw material	16,000m^3	1.00	16,000.00	
Supervisor	1	650.00	650.00	
Labour and other staff	12	300.00	3,600.00	
Other expenses			500.00	
			TOTAL EXPENDITURES	20,750.00
			Net income per day	9,250.00
			Net income per year	3,376,250.00

Again, the here presented economic analysis lacks a wide range of information, which was not accessible to the study team. This situation is similar in any of the case studies: the so-called feasibility studies for each of these projects reflect more the desires and expectations of the investor / operator / future owner than facts.

Challenges:

In addition to the above-mentioned limitations, the economic feasibility of the RDA-CBG project depends on

- the availability of cow dung to produce the calculated minimum amount of 400m^3 of biogas/day
- the continuous marketing of bio-fertilizer
- funds or affordable loans for running the CBG station not only on experimental but on commercial basis (funds for adaptation of vehicles, for marketing, for networks, …)
- constructed volume of the biogas system to receive the required amount of substrate for the intended results

Currently, the 3 digesters with expected daily gas production (EDGP) of $60m^3$ each are too small to produce the expected amount of 400 m^3 of biogas. This is also linked to the fact that at present the required amount of cow dung is not available on site.

Potential:

In case, the project will extend its operation, environmental benefits will be achieved, and the project will significantly contribute to reducing the national dependency on imported chemical fertilizers. It further will play a crucial role in showing how to substitute and extend the use of national natural gas.

4.1.5 PROJECT: SAHARA BIOGAS CNG

Size:	3 fiberglass digesters of $20m^3$ digester volume each with an expected daily gas production of 30 m^3
Owner:	Alhaz Sagir Chowdhury
Address:	Kashias, Potya, Chittagong
Contact Person:	Khokon Das; phone: 01820412141
Service Provider:	Khokon Das

The project was proposed

- To generate biogas for CBG
- To produce bio-fertilizer.

According to Khokon Das, a CBG station will be installed with a CBG target production of $300m^3$/day. Investment cost are summing up to BDT 10,000,000.00.

Cow dung as substrate will be collected from nearby cattle farms.

The project was financed by Mr. Alhaz Sagir Chowdhury. The design of the fibre glass digesters and the CBG station was developed and implemented by Khokon Das.

Overall Status:

Three fibre glass digesters were installed, two are under working conditions. According to the service provider’s assumption, daily CBG production will be about

300m^3; selling price of CBG will be BDT 35.00/m^3. The selling price of pre-sundried bio-fertilizer will be BDT 5.00/kg.

It must be noted that all the assumptions given by Khokon Das are not calculated based on scientific research, as the service provider has no academic engineering knowledge about anaerobic digestion and related technologies such as upgrading biogas to bio-methane for further processing as CBG. However, it should be emphasized that his interest and courage to develop his own advanced biogas technology components *(which exist already at implementation level in countries like China, Germany, UK and Sweden - just to name a few),* and to invest own money in testing them, cannot be valued high enough in view of a market development for advanced biogas technologies in Bangladesh. While other service providers stick to the fixed dome model, which is not appropriate for agro-industrial biogas plants, the owner and operator of Khokon Das experiments with to date technology components and material, although he has no academic education. Nevertheless, his practical knowledge, his proven interest, investment and curiosity in technical innovations qualifies him for appropriate training in to-date-biogas technologies. Without any pre-judgement and barriers, he, in the best tradition of many great inventors, probably would have the capability to come up with a feasible CBG project.

Challenges:

1. The volume of the three fibre glass digesters is too small to produce the required volume of biogas.
2. The capacity of CBG processing equipment is not sufficient.
3. The service provider has neither scientific nor technical knowledge on how to calculate the expected biogas production and CBG production.

As soon as the above-mentioned challenges would be solved, the potential daily balance between expenditures and income will be as follows:

Activity	**Expected daily amount**	**BDT/unit**	**BDT/activity/day**	**BDT total/day**
Selling of CBG	300 m^3	35.00	10,500.00	
Selling of Bio-fertilizer (if!)	2,700 kg	5.00	13,500.00	
			TOTAL INCOME	24,000.00

Activity	Expected daily amount	BDT/unit	BDT/activity/day	BDT total/day
Purchase of raw material	13,000 kg	1.00	13,000.00	
Supervisor	1	650.00	650.00	
Labour and other staff	9	300.00	2,700.00	
Other expenses			500.00	
			TOTAL EXPENDITURES	17,350.00
			Net income per day	6,650.00
			Net income per year	2,427,250.00

Potential:

Although the Sahara CBG project is currently still far away from the economic break-even-point, and being successful in a single-focused economic aspect, the project idea has a strong potential to become an agro-industrial showcase biogas project in Bangladesh. The project is selling test-wise compressed biomethane for local taxi and is testing bottling. It will be feasible depending on the availability of funds for the construction of better performing digesters to achieve the targeted production of 400m^3 biogas and to guarantee the delivery of enough cow dung (and other organic material) required for this amount of daily biogas production.

4.1.6 PROJECT: MAUSHUMI MULTIPURPOSE KHAMAR

Size:	2 fixed dome digesters, each with 71m^3 EDBP capacity
Owner:	Alhaj Abdur Rashid
Address:	Boalkhali, Chittagong
Contact Person:	Phone: 01715266428
Service Provider:	Masum Biogas

The project was proposed

- To run a bakery industry with biogas
- To generate electricity from biogas
- To use of bio-fertilizer on own land

The project was designed for 20,000 layer hens; the budget is estimated at BDT 500,000.00. It was financed by Md. Ashraf Hossain Masud. The design of the biogas-to-power plant was developed by Masum Biogas as technical service provider. The expected daily gas production (EDGP) is 142m^3; 600kg of sundried organic fertilizer should be produced per day.

The basic design parameter and assumptions are as follows:

- Droppings from each bird = 100 g/day
- Addition of fresh water in the ratio 2:3 to liquefy the substrate and lower the TS of manure
- Biogas production per kg of dropping: 0.07 m^3
- Sun dried fertilizer production: 25g/bird/day

Overall Status:

The farm keeps 25,000 layer hens in 2 multi-storied bird houses. In addition, 15 cows are kept on the farm. Two digesters were constructed to utilize the litter. Litter and water is directly drained into the digester through a small inlet. Workers clean out sand and sediment from the digesters at an interval of 3 years.

Biogas is used to run a commercial bakery and to generate electricity. Average consumption of biogas is 142m^3/day. Some untreated poultry litter is directly sundried and applied to own land.

Plant construction started in January 2006 and was completed in April 2006. A first operation test was performed in April 2006. The regular operation of both generator and bakery industry started in June 2006. Initially, the bakery industry was running and at the same time the 10kW generator was in operation. Since the expansion of the bakery industry, presently total biogas production is used for the industry. The generator is therefore not in operation at present.

The inlet is very small. There is no opportunity installed for solids and sand to settle before entering the plant.

The dome digesters are round and constructed with brick-cement masonry. A reinforced concrete dome was casted above the digester. The top dome is well seen above the ground. There should be a device to check the given maximum design gas pressure.

A rectangular hydraulic chamber is constructed adjoining to the digesters. The hydraulic chamber is covered with heavy concrete slab to avoid that slurry splashes into the surrounding of the hydraulic chamber.

As common in fixed dome digesters biogas is stored within the dome, in the upper part of the biogas digester.

For slurry management, pits are made beside and on top of the dome with a shallow pond nearby. The pit is not lined, which causes leakage of organic loaded liquid and nutrients into the ground, with a considerable risk to pollute groundwater resources.

However, the flexible hose piping system is not professional and does not follow the rules and regulations of GoB for natural gas.

Challenges:

- Use of too much fresh water up to 2/3 of the entire volume
- Piping is not professional and not properly aligned; Bangladesh natural gas standards are not respected. At least there is a water trap included to remove condense water from biogas.
- Cleaning of digesters at an interval of 3 years
- Marketing of bio-slurry: the owner is using liquid and sundried slurry on his own land. Only a part of sundried slurry is sold to local farmers.

The case of Maushumi Multipurpose Khamar demonstrates that biogas technology could promote other industries by providing a reliable renewable clean energy source. It also shows the importance of correct design and convenient operational procedures for a consolidated long-term energy supply.

In this case study, too, the owner did not provide more detailed financial and economic data on capital and operational costs, which would have facilitated a detailed economic analysis.

5. Benchmark analysis of existing agro-industrial biogas plants

5.1 Benchmark Assessment Methodology

Benchmarking in the traditional sense refers to the search for the best practices that lead to top performance. A benchmark in this sense is a reference point of a measured peak performance, towards which the operators should strive for [1].

Efficiency can generally be described as the relationship between benefit and effort. Are the benefits and efforts in form of "energy", the result is an energy efficiency or degree of utilization.

5.1.1 Data Envelopment Analysis (DEA)

For measuring of efficiency, the method of "Data Envelopment Analysis" (DEA) can be applied [1, 2]. DEA is a mathematical programming method and is widely used to compare efficiency by using defined input (e.g. amount of feedstock, labour, energy consumption, investment cost, etc.) and output factors (e.g. produced net amount of electricity, utilized heat, etc.); it is specifically used for determination of an efficient frontier of a particular production process, which is formed by the most efficient (best practice) of the considered systems. Relative to a specific efficiency frontier, the efficiency of all other units is measured. By comparing the units (biogas plants) with the efficiency frontier (best in the sector) is commonly known as "benchmarking". [1].

The good performance of a biogas plant depends on various parameters; their interdependence makes the evaluation of a biogas plant performance and efficiency a challenging task. DEA offers one possible approach to evaluate the relative efficiency of a comparable and homogeneous group of "units", known as the Decision-Making Units (DMU). In the present study, DMU refers to biogas plants, which are forming a homogeneous group as systems for energy conversion. It is assumed that these units perform the same function by converting many "inputs" into several "outputs" [2]. The DEA approach has been already used by other studies to evaluate the (relative) efficiency of biogas plants [3, 4, 5, 6].

The result of a DEA evaluation is the measure of how efficient the “input” is converted into an “output” among the evaluated units. The efficiency measure ranges in the interval 0 to 1. The "best" (benchmark) unit receives the value 1, while the "worst" (inefficient) unit receives the lowest value that has always to be greater than 0. [3].

The efficiency ratio can be displayed for any number of inputs and outputs with the following formula:

$$\text{Efficiency} = \frac{\text{Weighted Output Sum}}{\text{Weighted Input Sum}} \qquad \frac{\Sigma_i q_i y_i}{\Sigma_j q_j x_j} \tag{1}$$

Factors y_i and x_j represent output and input, respectively, and q_i and q_j represent the values (weight factors) determined by the applied DEA method in optimal way. Optimal in context of linear programming means that the weighting factors are selected in a way that the efficiency value is maximized under the constraint that the efficiency value of any unit is not greater than one [1, 2].

DEA models can basically be divided into two approaches oriented either on the input or the output. Output-oriented analysis measures if the output can be increased by constant input, while the input-oriented approach measures how far the input can be reduced by maintaining constantly the output [1, 2]. To increase the output of a biogas plant, an output-oriented approach seems to be appropriate.

Another important point in DEA analysis is the sufficient number of Decision Making Units (DMUs). If the number of DMUs is less than the sum of in- and outputs, then there is a loss of ability to distinguish between the efficient and inefficiently DMUs. It is therefore desirable that the number of DMUs considered in the analysis is exceeding the number of all in- and outputs [1, 2].

Also, the choice of models in the DEA analysis is an important topic since different models can be applied. The two most common models applied in studies for biogas plants assessment are the Charnes-Cooper-Rhodes (CCR) -model[5] developed 1978 by Charnes, Cooper and Rhodes and the Banker-Charnes-Cooper (BCC-model[6] in 1984 by Banker, Charnes and Cooper [1, 2].

The CCR-model is based on the radial minimization / maximization of all inputs / outputs and assumes an environment of Constant Returns to Scale (CRSs), which

[5] Named after its inventors Charnes, Cooper and Rhodes
[6] Named after its inventors Banker, Charnes and Cooper

implies that DMU operates under constant returns to scale, meaning that increase of inputs results in a proportionate increase in the output levels [1]. This condition can be also assumed for biogas plants, for example the production of biogas is proportional to the dry and organic matter content. By identifying the Efficient Frontier (EF) under CRS (Constant Returns to Scale), which is represented by the most efficient DMU, all DMUs below the EF are relative inefficient but within Production Possibility Set. The inefficiency of DMUs is measured by its distance to the Efficient Frontier – refer to the following Figure.

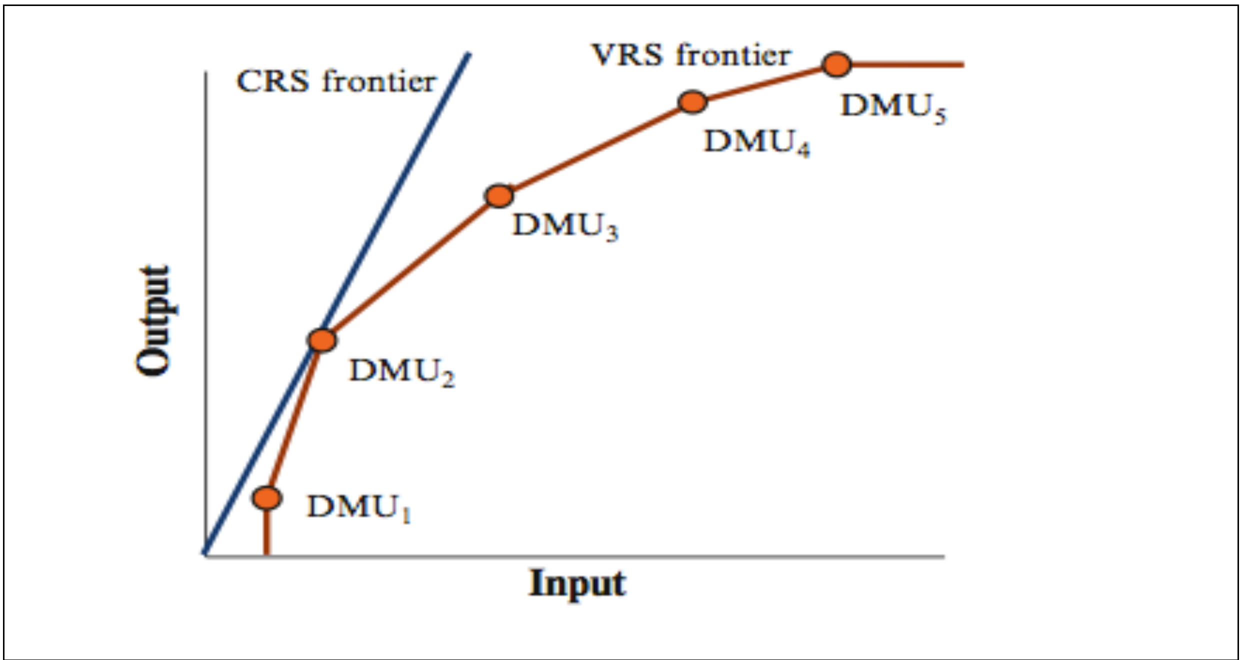


FIGURE 4: DEA MODEL [1]

The BCC model assumes variable returns to scale (VRS). That implies that the any increase of inputs/outputs does not result in a proportional increase of outputs/inputs this assumption influences the determination of EF. It should be noted that the efficiency score in BCC-model always will be greater than with CCR-model, and hence the number of DMUs considerate as efficient.

The choice of the DEA model itself can influence the ranking of the single DMUs however all models shows similarity in determining the relative efficiency/inefficiency of biogas plants [7].

Even if the approach is not sufficient to determine the absolute efficiency of the system and to describe the processes of biogas production and utilization. Is it sufficient to determine with empirical character the efficient/Inefficient groups, to show efficiency gaps and to set the benchmark [7].

The disadvantages of DEA model have been described in flexibility to choose different In- and Output factors, in a way that certain undesirable In- or Output can be effectively ignored and putting the DMU in the best possible light [5]. Moreover, the DEA approach evaluates all in- and output as equal, for example, if the factors have been selected without reference to reality, primary and secondary Inputs considered by DEA model to be equal. In addition, anytime the number of in- and outputs factors grows, the tendency goes that more DMUs become [5]. Another disadvantage of the model was described in the need of having the DMUs set with comparable production levels because of scale effects. For example, a very large unit can be efficient because there is no other with a similar production level or in contrast very small units are often recognized as scale efficient [5].

5.1.2 DATA COLLECTION AND SAMPLE SIZE

Initially 228 biogas plant were documented as commercial, from that 102 owners of biogas plants responded to a telephone survey, and 28 were also taken the visited plants by BBDF and GERBIO. A total of 120 data sets from biogas plants were collected, but after the internal agreement on the working definition of Agro-Industrial Biogas Plants, between GIZ, BBDF and GERBIO (minimum size defined by through expected/designed daily biogas production capacity of at least $50m^3$ per system) multiple biogas plants at one farm site feeding the same generator set or a mini-gas-grid were considered as one system. The initial number of 228 identified Commercial Biogas Plants were so reduced to 113 Agro-Industrial-Plant Systems, out of which 70 owners and operators responded; thus, the sample size of 70 has a confidence level of 95% and interval of 7%. Both, confidence level and interval were calculated with the online tool http://www.surveysystem.com/sscalc.htm

The data collection was conducted for 34 plants again by telephone survey and for 36 plants during field visits, five of them were contacted in both ways (phone and visit). It was based on a structured smart questionnaire available in hard copy as well as in digital form using the smart phone application ‘Data Field’.

5.2 STATISTICAL ANALYSIS

The statistical analysis revealed that construction of Agro-Industrial-Biogas plants (AIBP) in Bangladesh increased from 2009 onwards, one year after the “Renewable Energy Policy of Bangladesh” was approved; 2011, 2012 and 2013 were the years when most of AIBP construction took place.

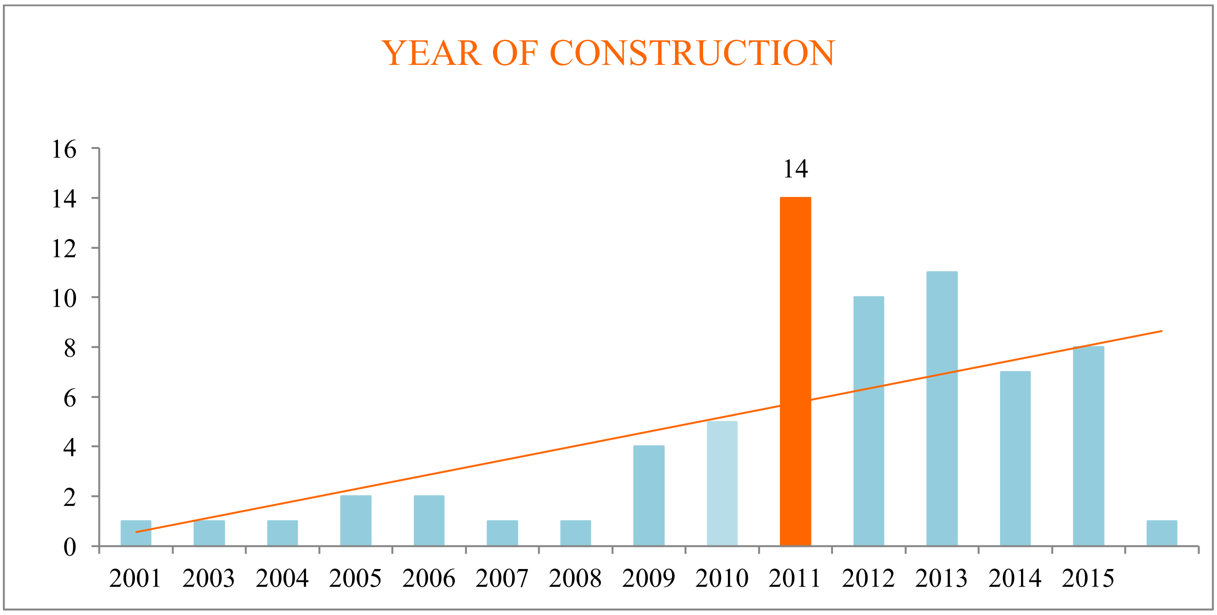


FIGURE 5: YEAR OF CONSTRUCTION OF ANALYSED AGRO-INDUSTRIAL BIOGAS SYSTEMS

The most common sizes of agro-industrial biogas plants (AIBP) in Bangladesh range between 6 to 49m^3 – as such assigned to category E and shown in Figure 6. However, the definition of AIBP in this study considers only AIBP from 50m^3 onwards as real ”industrial” plants; therefore, the biggest number of assessed AIBP belongs to category D: 50 – 99m^3, as shown in the chart. The volume (daily expected biogas production) of 60m^3 is the largest group among this category with a total of 34 plant systems assessed. As mentioned previously, the distinction between the groups is based on expected daily biogas production, the common way for size indication in Bangladesh and not by digester construction volume.

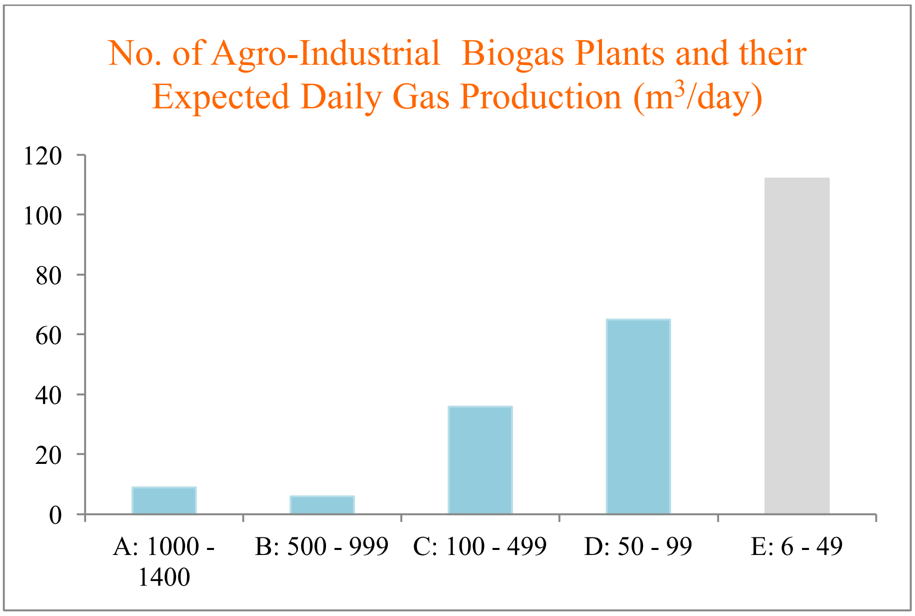


FIGURE 6: AIBP GROUPED BY THEIR EXPECTED DAILY GAS PRODUCTION

More than 50% of AIBP operators reported to have received financial support for the construction of their biogas plant: 50% in form of loan and additional 13% in form of loan and subsidies. The remaining 37% of AIBP were financed only through the own funds of the owner / the owning enterprise.

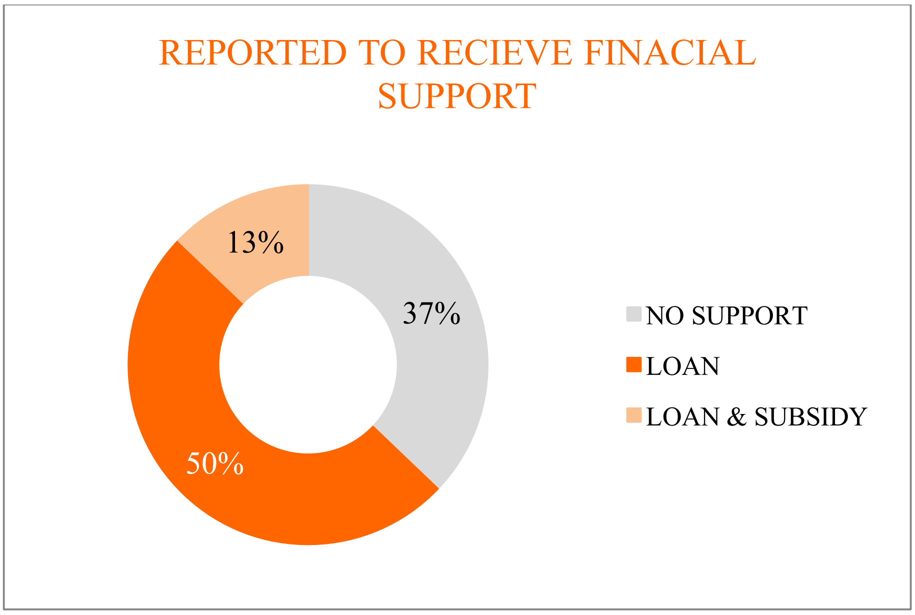


FIGURE 7: RECEIVED FINANCIAL SUPPORT

In both markets for financial services and for construction of AIBP, Rural Development Academy (RDA) is the biggest stakeholder, with 36% for both financial services and construction, followed as service provider for financial support by

IDCOL at 11%. 3% of all owners stated that GIZ was involved through design and as technical supporting agency in their project, but not for financial support.

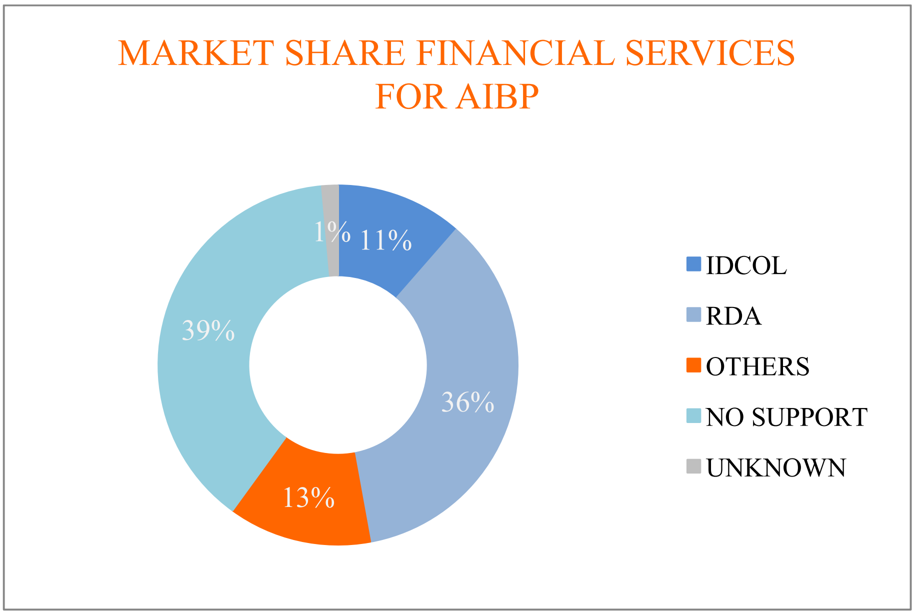


FIGURE 8: MARKET SHARE OF FINANCIAL SERVICE PROVIDERS

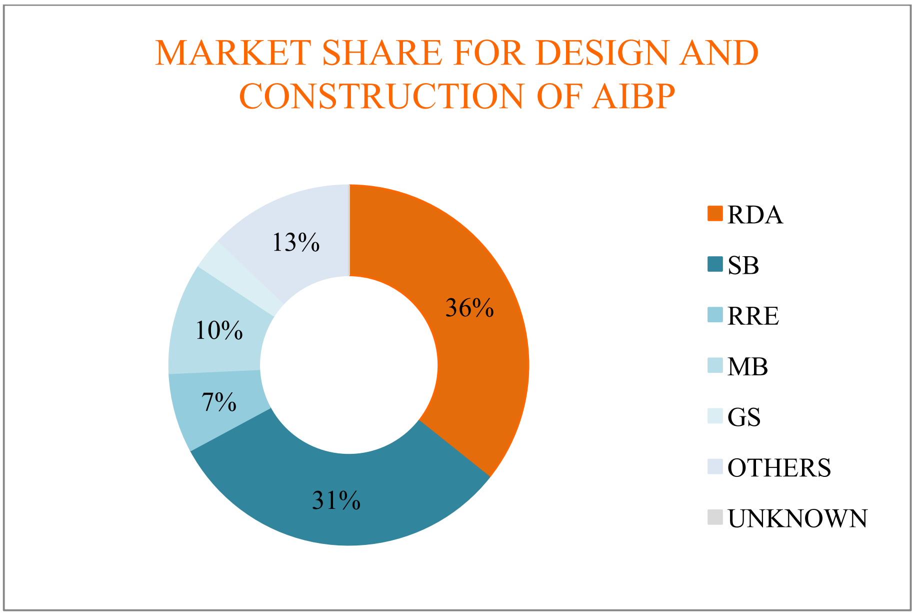


FIGURE 9: MARKET SHARE FOR DESIGN AND CONSTRUCTION

In the AIBP construction sector, Seed Bangla with 31% is by far the largest actor, followed by Masum Biogas (10%), Rahman Renewable Energies (7%), and Grameen Shakti (3%).

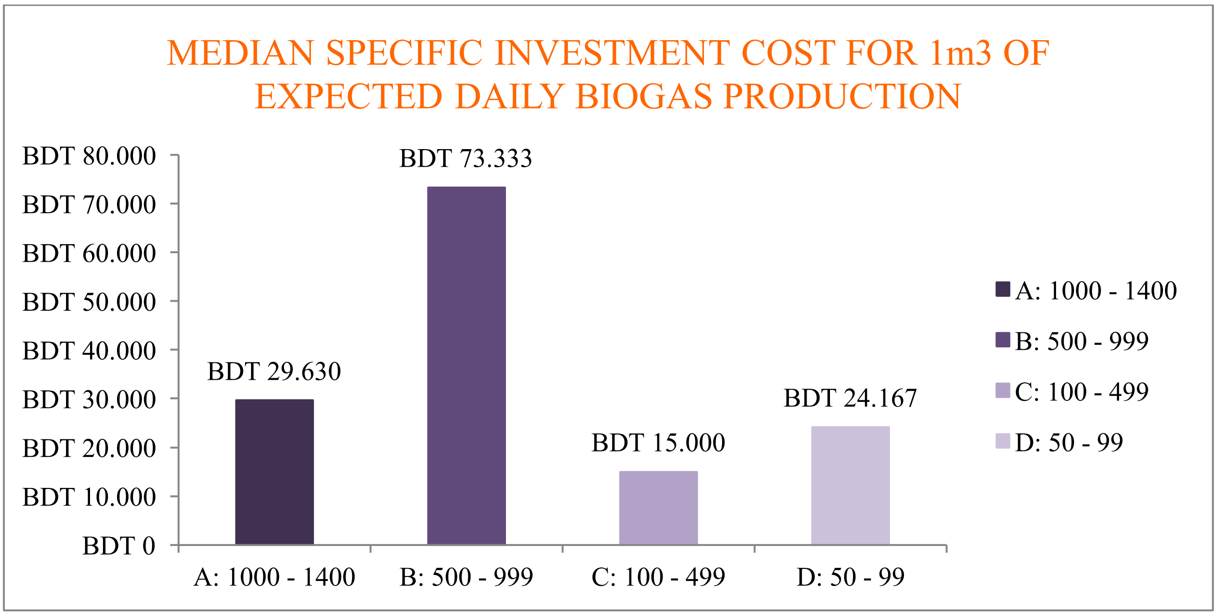


FIGURE 10: MARKET SHARE FOR DESIGN AND CONSTRUCTION

The median for specific investment cost of 1m^3 expected daily biogas production capacity is with BDT 15,000 for category C (100 – 499m^3) the lowest and for category B (500 – 999 m^3) with BDT 73,333 the highest.

During the survey from March to June 2016, 80% AIBP reported to be in operation, from that 6 plants or 9% however only partly, that means that only a part of constructed digester capacity where operating. In total 8 plants (11%) where no more active by the visit or interview moment for various reasons, the construction of one plant was just accomplished and the operation was not yet started. Another mentioned reason for stop of operation are lost of the entire livestock in one case caused by bird flu, selling their livestock, changing the business model or – very important - no solution for the highly diluted bio-slurry management, and due to construction failures.

Operators of AIBP reported to use only poultry (51%) and cow manure (49%) for anaerobic digestion. Usually it was recommended by the technical designer that the substrate is mixed with fresh water in 1:1 ratio for cow, and 1:2 for poultry manure, therefore the total daily consumption of freshwater for biogas production was reported to be 318,310 litres/day or to produce 1m^3 of biogas in average 30l of fresh water are necessary. The digestion occurs all in one step digestion, where one unit (53%) is operating, or more (29%) in parallel mode, all under ambient temperature and mainly in mono substrate digestion in 59 cases (95%) compared to co-digestion in 3 plants (5%).

In addition, the operators of AIBP evaluated their biogas systems as "fully operational", "partly operational" or "not operational". The study team must rely on this evaluation, because at none of the plants measuring devices are installed that could deliver proofs for the performance achievements of the system. To provide a solid data base from and to the Bangladesh Biogas Sector, AIBP should all be equipped from their start-up with up-to-date measurement devices.

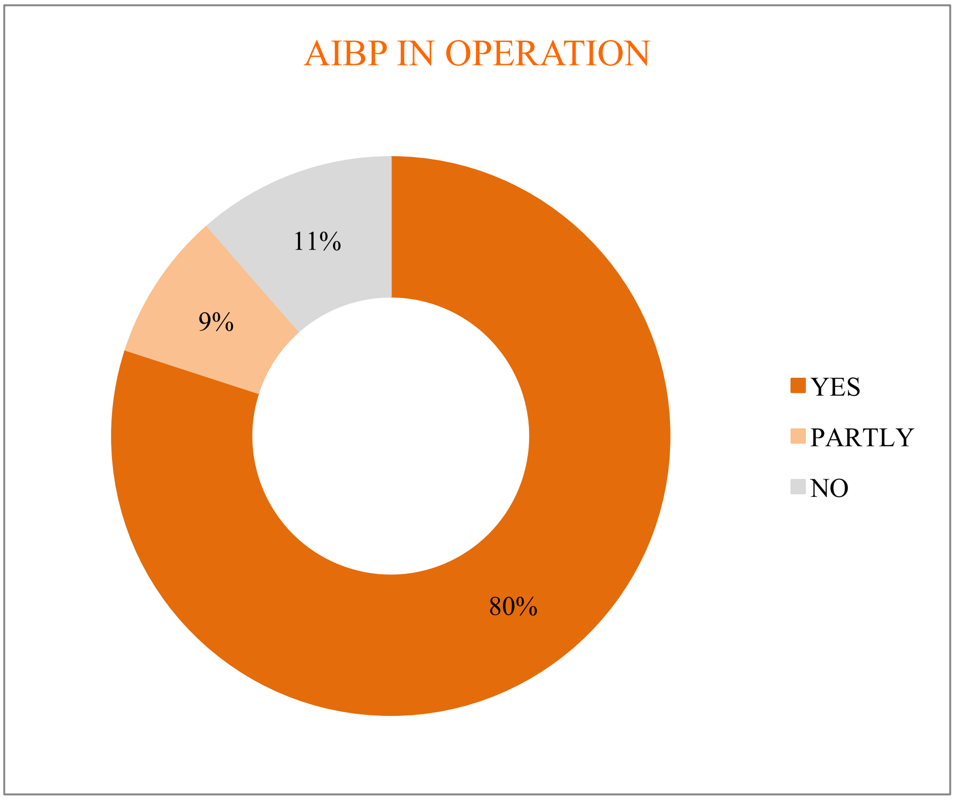


FIGURE 11: AGRO-INDUSTRIAL BIOGAS PLANTS IN OPERATION

Overall, 73% of AIBP operators reported to own a biogas fuelled generator for electricity production with an installed electrical capacity totalling 2.29 MW, even if 83% of the industrial-sized farms are connected to the grid. The reported daily generated amount of electricity is 3.21MWh; that can be theoretically covered by 1.75h *(3.21MWh / 2.29MW / 0.8 = 1.75)* of daily operation at 80% load (which is considered as maximum load with biogas for converted diesel or gas engines), indicating that the average utilization of the installed generator capacity lies at only 7.3% *(1.75h / 24h)*.

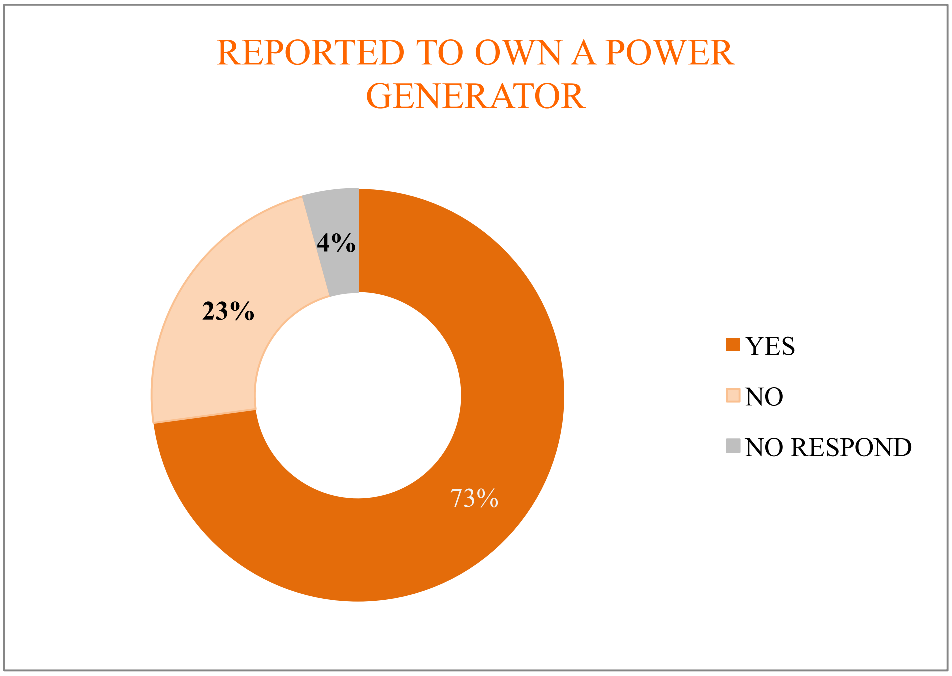


FIGURE 12: BIOGAS PLANTS WITH POWER GENERATOR

Even if only 50% of the installed generator capacity would be exploited, 21.98 MWh (2.29MW * 12h * 0.8 = 21.98MWh) could be provided daily as additional electrical energy for Bangladesh's grid. If it is possible to produce 1.25kWh with 1m^3 of biogas (25% electrical efficiency - as usual consumed in small size generators or in partial load use), 17,587m^3 of biogas would be required on daily basis.

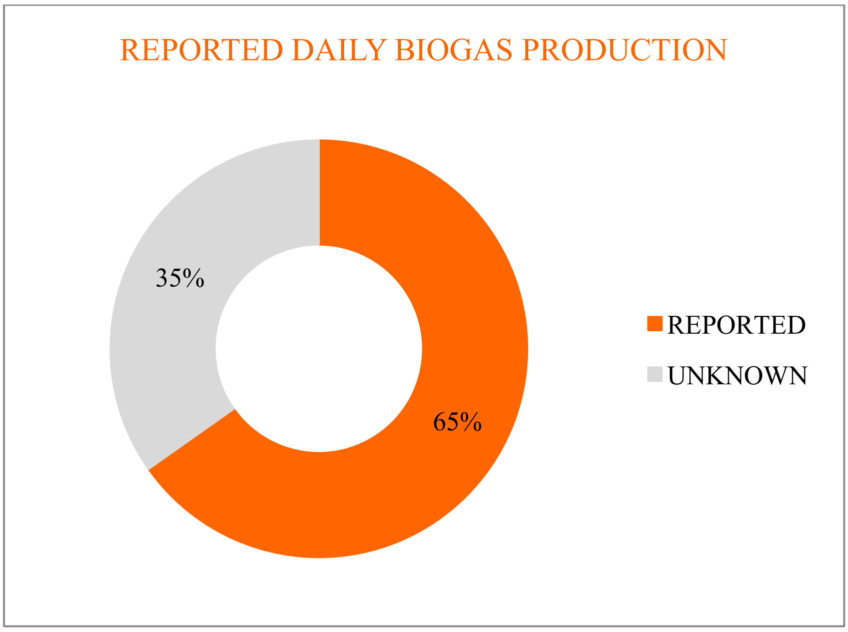


FIGURE 13: REPORTED DAILY BIOGAS PRODUCTION

However, even with the estimated biogas potential of the reported daily substrate input into all the assessed biogas plants, resulting in daily 10,845m^3 is not enough to provide enough biogas even to exploit 50% of the total installed generator capacity, is theoretically possible by 60%, this indicates that 40% overcapacity is installed. If referring to continues operation of the generator for 24h, (2.29MW * 24h *0.8 = 43.97MWh), then the installed overcapacity increases to 70% This indicates an overcapacity of installed engines in relation to the available substrate. If one uses the ideal planning values for expected daily biogas production of plants that are equipped with generator, so is the planned overcapacity, to exploit 50% of the installed capacity, lies by 20% and for continues operation for 24h, by 59%.

More than the half of operating AIBP, 61% reported to supply biogas into a mini-gas grid and provide gas to totally 1,350 families for cooking.

Another possible use of biogas is upgraded by water scrubbing to biomethane and bottled in a compressed form so called CBG, and used for example as a fuel in vehicles. Only two of the assessed AIBPs (4%) included this approach in their design, another 10 (14%) are planning to extend the biogas use in this direction; however, 67% of the operators were not yet aware about this technology for advanced biogas application.

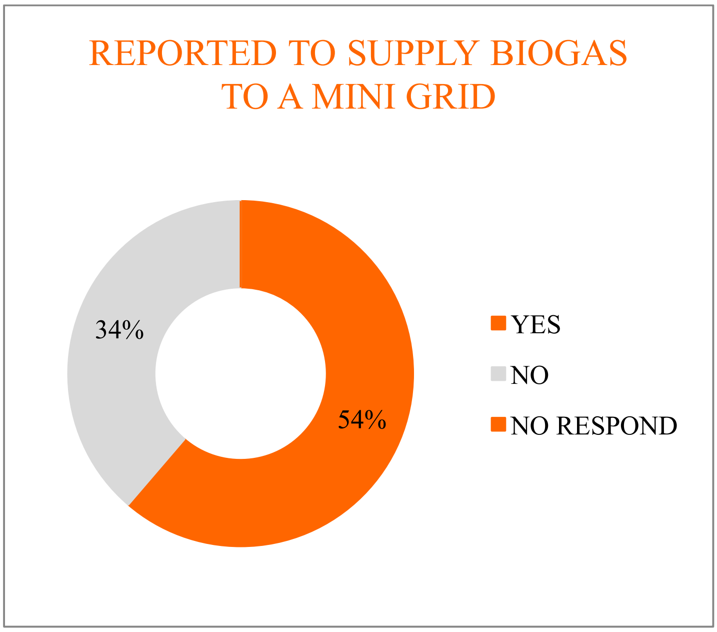


FIGURE 14: REPORTED SUPPLY TO MINI GRIDS

The median for working hours, required for the daily operation of an AIBP, was reported to be 8h for AIBP category C, and 6h for AIBP category D – the as lowest labour input. In category A the median is 10h, obviously the category requesting the highest work efforts.

Altogether the correspondent AIBPs to date allow to establish 259 permanent on-site working places.

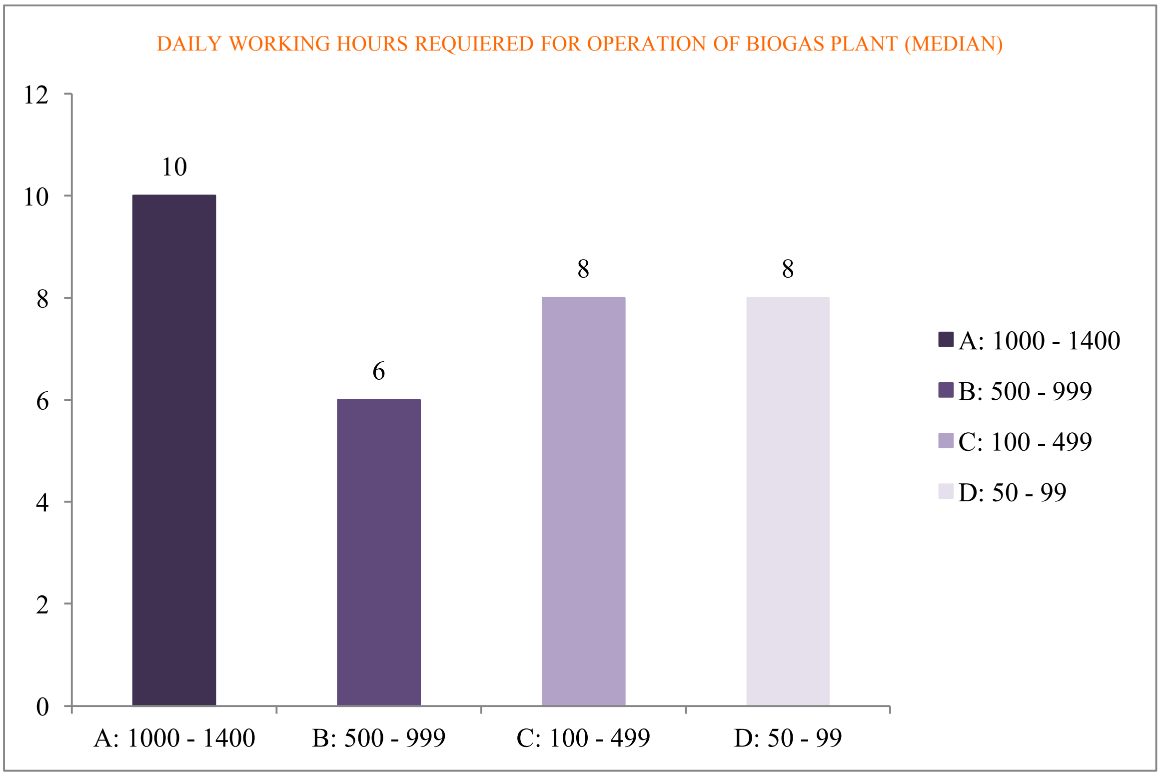


FIGURE 15: DAILY WORKING HOURS REQUIRED FOR OPERATION OF BIOGAS PLANT

65% of the operators of AIBPs reported to use slurry as a fertilizer; thereof 27% for commercial use, i.e. sale only, 16% for sale and own use; and another 13% only for their own farm needs. Still 19% are discharging the bio-slurry at least partially uncontrolled into public surface water bodies. The remaining 15% of operators are storing the slurry in lagoons, but without having any further use in mind.

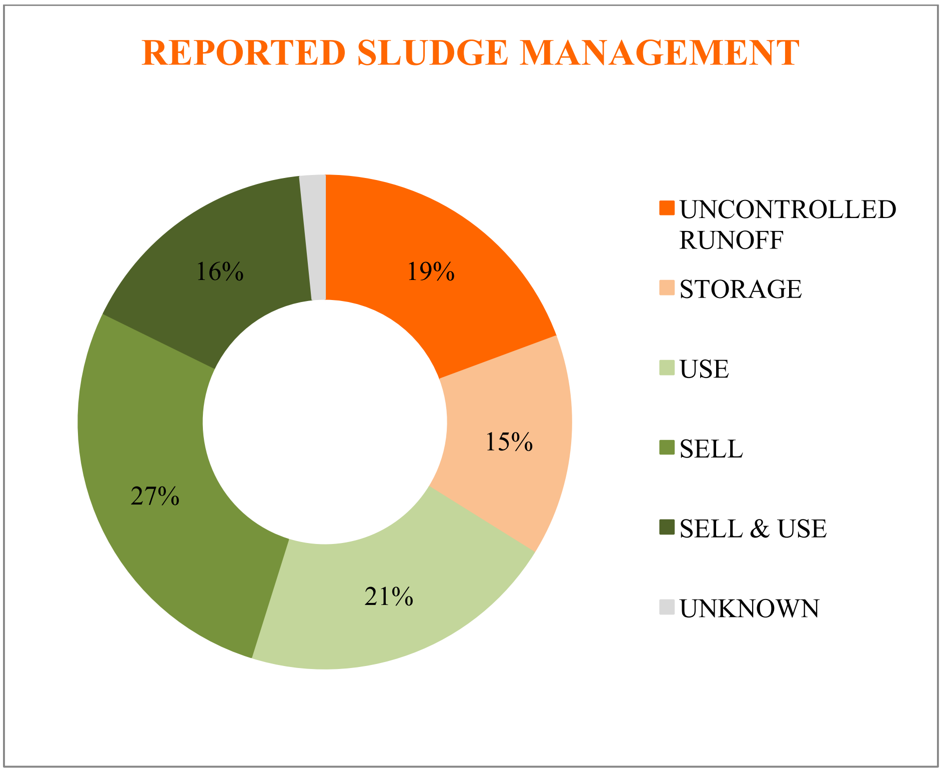


FIGURE 16: REPORTED SLUDGE MANAGEMENT

5.3 DEA BENCHMARK ASSESSMENT

As it is shown in the Figure 17, from the total sample of 70 AIBPs, 14 (20%) plants were not in operation or only partly, 17 (24%) of responses from operators were incomplete. Because one defined criteria of an efficient biogas plant are the use of slurry as bio-fertilizer or soil improver, 19 (27%) plants could not be included into the final data analysis due to not existing slurry management. After additional plausibility analysis, another 4 (6%) plants were dismissed, hence the reported amount of biogas or effluent slurry was much higher than the reported amount of daily input material or the daily biogas production capacity.

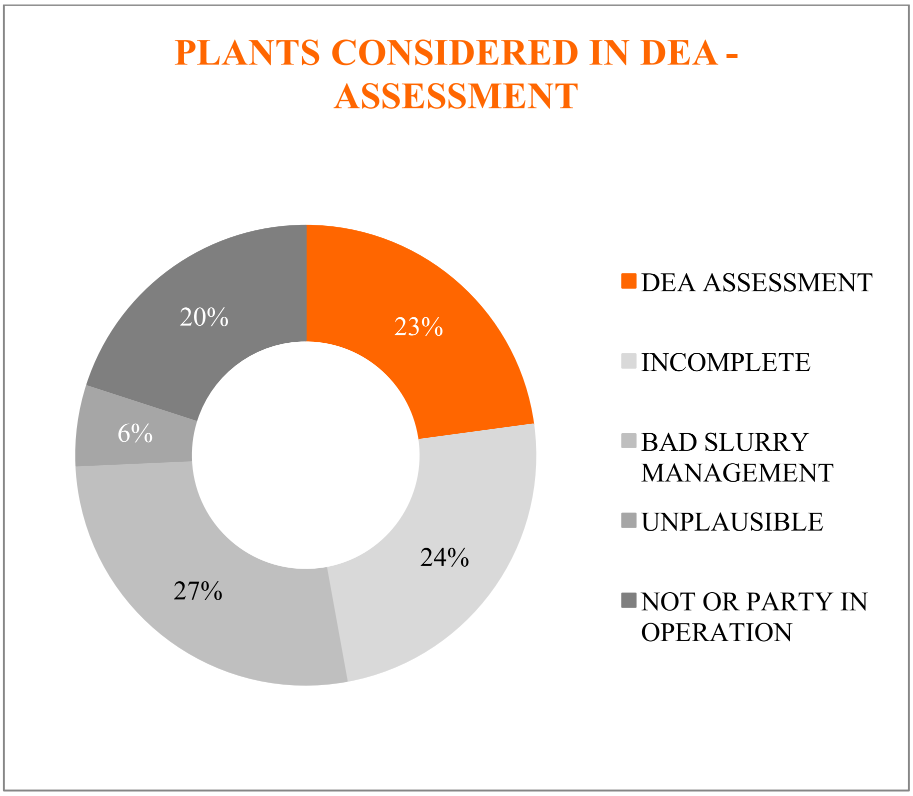


FIGURE 17: PLANTS CONSIDERED IN "DEA" ASSESSMENT

The 16 remaining plants were assessed with the help of DEA online tool (http://www.dea.fernuni-hagen.de), provided by the Distance Learning University Hagen, Germany and applying defined in- and output factors as described in the following table.

Table 4: In- and output factors

Set	Indicator	Unit
Input 1 (I_1)	Total Investment Cost	[BDT]
Input 2 (I_2)	Labour	[h/d]
Input 3 (I_3)	Fresh Water Consumption	[l/d]
Input 4 (I_4)	Energy Input of Substrate	[h/d]
Output 1 (O_1)	Fertilizer	[kg/d]
Output 2 (O_2)	Biogas Production	[m3]
Output 3 (O_3)	Utilized Energy	[kWh/d]

The DEA assessment was conducted for 16 plants and is summarized in the following table.

TABLE 5: BIOGAS PLANTS AND VALUES USED IN THE ASSESSMENT

ID	INPUT1	INPUT 2	INPUT 3	INPUT 4	OUTPUT 1	OUTPUT 2	OUTPUT 3
477700	BDT 1,450,000	8	3000	666	1200	100	484
477701	BDT 1,450,000	8	2000	444	1150	65	294
477705	BDT 1,450,000	4	2000	444	1250	65	247
477708	BDT 1,450,000	5	1640	311	750	56	267
477710	BDT 1,450,000	3	1950	433	1100	65	309
477711	BDT 1,450,000	8	3200	710	1400	100	499
477781	BDT 1,150,000	8	1700	377	800	52	170
477795	BDT 60,000,000	8	16000	3108	4100	600	2096
477835	BDT 1,800,000	85	3500	777	1500	130	350
478028	BDT 1,000,000	2	2160	480	350	83	414
478035	BDT 4,800,000	16	8000	888	1000	100	230
478045	BDT 1,430,000	8	2000	222	500	60	140
478047	BDT 2,000,000	8	2000	444	500	60	263
478048	BDT 1,450,000	8	1700	377	450	60	247
478051	BDT 35,710,000	25	9000	1998	2151	300	958
478054	BDT 1,500,000	2	5500	1027	675	192	192

For benchmark assessment, both CCR (CRS) and BCC (VRS) were applied. As displayed in the following table, based on the obtained data, 11 biogas plants were analysed by BCC model and 9 by CCR model, to identify a benchmark for AIBP in Bangladesh.

TABLE 6: CCR AND BCC OUTPUT VALUES OF THE BEST PERFORMING AGRO-INDUSTRIAL BIOGAS PLANTS IN BANGLADESH

ID	CCR (OUTPUT)	BCC (OUTPUT)
477700	0.961969	0.983302
477701	0.974359	0.981921
477705	1	1
477708	1	1
477710	1	1
477711	1	1
477781	0.86707	1
477795	1	1
477835	1	1
478028	1	1

ID	CCR (OUTPUT)	BCC (OUTPUT)
478035	0.159257	0.456097
478045	1	1
478047	0.743591	0.778853
478048	0.928038	1
478051	0.863128	0.874447
478054	1	1

However, to narrow down to the currently most efficient groups, the CCR model can be used, because of the CRS nature of the biogas production: the production of biogas is proportional to the dry and organic matter content of the input substrate, in this case the energy input of the substrate. Therefore, 9 (12%) of the AIBPs were identified as a Benchmark for Bangladesh by CCR model.

TABLE 7: DETAILS ON THE NINE OBVIOUSLY BEST PERFORMING AGRO-INDUSTRIAL BIOGAS PLANTS

ID	PROJECT NAME	LOCATION	SIZE	FINANCIAL SERVICE PROVIDER	TECHNICAL SERVICE PROVIDER	FEEDSTOCK MATERIALS	ELECTRICITY PRODUCTION	GAS SUPPLY TO MINI GRID
477705	KACHIBARIA BIOGAS PROCOLO	KHULNA, NARAIL, LOHAGORA, KACHIBARI	60	RDA	RDA	COW	NO	YES
477708	MOJID FARM BIOGAS PROCOLO	RAJSHAHI, BOGRA, KAHALU, BAROMILE	60	RDA	RDA	COW	NO	YES
477710	BIOGAS UPOPROCOL PO	DHAKA, KHILGAON, NASIRABAD	60	RDA	RDA	COW	YES	YES
477711	KATAGORIA KRISHAK SOMBAI SOMITT BIOGAS	RAJSHAJI, BOGRA, SHAJAHAN, KATABARIA	60	RDA	RDA	COW	NO	YES
477795	PARAGON GROUP LTD	DHAKA, GAZIPUR, SHREEPUR, MAUNA	600	BRAC BANK	C&F/HEEE	POULTRY	YES	NO
477835	NRM BIOGAS (RDA)	RAJSHAHI, NAOGAON, NIAMATPUR, RUMKURHA	60	RDA	RDA	COW	NO	YES
478028	AHAD DAIRY FARM	CHITTAGONG, ROWGAN, GOHIRA	80	Own	MASUM BIOGAS	COW	NO	YES
478045	CHANDKARIM COMMINITY BIOGAS PLANT	RANGPUR, GAIBANDHA, SHADULLAPU R, CHANKARIN	60	RDA	RDA	COW	YES	YES
478054	MOUSUMI MULTIPOURP OSE KHAMAR	CHITTAGONG, BOALKHALI, BOALKHALI BAZAR	140	OWN	MASUM BIOGAS	POULTRY & COW	NO	NO

When breaking down by the different categories, the Category D (50-99m^3) is the most represented, with 7 plants identified as a benchmark for AIBP in Bangladesh, 6 of them were implemented by RDA.

Category C (100-499m^3) and Category B (500-999m^3) are represented within the benchmark with one plant for each of the two categories.

Category A (1000-2700m^3) is not represented at all; the reason is that from 5 respondents in this category, 3 reported to not use any portion of their bio-slurry, 1 plant was only partly in operation and another operator reported implausible values related to feeding amount and biogas production.

The results of the benchmark assessment reveal that the best performing AIBP are most commonly represented in Category D (50-99m^3) with 7 identified plants. This can be attributed to the following reasons: (1) it is the most common volume of AIBG in Bangladesh; (2) feedstock material used in the benchmark group is exclusively cow manure, which is known to achieve higher biogas yields than poultry droppings. Comparing with Category A (1000-2700m^3), it is obvious that the larger plants are more challenging to be operated, especially in terms of slurry management and process stability.

In Category C (100-499m^3) and B (500 -999m^3) both remaining plants are fed with poultry droppings.

In average, the identified benchmarking plants generate 0.6m3 of biogas from each m3 of digester volume and thus more than the average of 0.5m3 among non-benchmark plants in Bangladesh.

3 out of 9 AIBPs in Bangladesh identified as benchmark plants are reported to generate electricity, 2 in Category D (50-99m^3) and 1 in B (500-999m^3), in average the generator availability among the benchmark plans, lies by 11% and thus higher than the average in Bangladesh with 7.3%. Estimated volume specific electricity production, lead to the similar conclusion of 1m^3 of digester volume among the benchmark group produces in average 0,22kWh/m^3, more electrical energy than the average with 0.15kWh/m^3.

As for the specific investment cost for each m^3 of expected daily biogas production, the median for category D (50-99m^3) is the same for both, benchmark and non-benchmark group with BDT 24,167. For the benchmark plant in Category C (100-499m^3) the specific investment costs are significantly higher with BDT 35,714. If compared to the median of the non-benchmark biogas plants of BDT15,000. Similar results exist for category B (500 -999m^3), where the median for the non-benchmark plants is at BDT 73,333 lower compared with the benchmark plant at BDT 100,000.

Water consumption for the benchmark plants is as expected: to produce 1m^3 biogas, the best performing AIBP use with an average of 29 litres up to 7 litres less than the general average of 36 litres.

Conclusion

AIBPs in Category D (50-99m^3) work best with cow manure as feedstock, since 7 plants (20%) out of 34 are in this category, could be identified as benchmark, from that six where implemented by RDA.

The larger the size of AIBP the smaller is the share of the efficient plants within the category: only 1 (4%) out of 25 plants were identified as efficient in category C (100-499m^3). Also in category C, 7 plants (28%) were not or only partly in operation.

5.4 Economic potentials of agro-industrial biogas plants in Bangladesh

To evaluate the economic potentials of agro-industrial biogas plants in and for Bangladesh, the consultant added a sensitivity analysis in the study, although it must be announced that most of the economic data and further information used for the different scenarios were obtained from parties with specific interest in the sector: biogas system owners and service providers. At none of the surveyed agro-industrial biogas plants control devices are installed; therefore, exact measuring neither of biogas production and consumption, nor of electricity production and consumption was possible, therefore cross-logic-calculations have been made. According to international industrial and business standards, these measuring devices are indispensable equipment for medium and large scale agro-industrial biogas plants, as the data they are producing supports not only the efficient operation of the biogas system, but also gives hints on the economic and ecologically sound functioning of the system. Both, financial and technical service providers should have a high interest in installing such devices right from the beginning of the operation.

TABLE 8: IN- AND OUTPUT MATERIALS, SAME AS FOR DEA

Set	Indicator	Unit
Input 1 (I_1)	Total Investment Cost	[BDT]
Input 2 (I_2)	Labour	[h/d]
Input 3 (I_3)	Fresh Water Consumption	[l/d]
Input 4 (I_4)	Energy Input of Substrate	[h/d]
Output 1 (O_1)	Fertilizer	[kg/d]
Output 2 (O_2)	Biogas Production	[m3]
Output 3 (O_3)	Utilized Energy	[kWh/d]

In is proposed that an in-depth study jointly intended by the Bangladesh Agricultural University (BAU) and the University of Science and Technology Beijing (USTB), should analyse the 9 best performing biogas plants by installing specific measurement equipment. Best is to undertake these in a proper scientific study about performance and sensitivity analysis compared to the key predictions. Due to national security reasons the field work with international students this study was possible to complete, and is now proposed as one “road map” activity to be implemented as soon as possible.

It is a technique used to determine how different values of an independent variable will impact a dependent variable under a given set of assumptions. Applied within specific boundaries it depends on one or more input variables, such as the effect that changes in electricity consumption tariffs will have on feed-in-grid-tariffs for biogas-to-power plants. [7]

For the Sensitivity Analysis, the following variables have been selected:

1. Costs for feedstock purchase
2. Benefits from farm-internal electricity consumption
3. Revenues from biogas sale
4. Revenues from fertilizer sale

As fixed costs, the following budget items were defined:

[7] http://www.investopedia.com/terms/s/sensitivityanalysis.asp

1. Construction cost for entire biogas system including digester, biogas storage, piping from digester to generator, generator, slurry storage ponds and other processing equipment, and costs for biogas and electricity supply to farm-external clients
2. Costs for biogas upgrading equipment
3. Cost for labour and supervision

Per definition the period of depreciation for construction and equipment will be set at 20 years.

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6. STAKEHOLDER ANALYSIS AND INVOLVEMENT

Potential stakeholders in the agro-industrial biogas sector include a broad range of institutions, enterprises, associations and individuals: everybody who is involved in agricultural and energy activities, and everybody who is producing organic waste either from animals, crops, and food and feed processing. In addition, specialized enterprises for construction and installation of anaerobic systems and appropriate equipment, fertilizer companies and marketing experts, policy makers and neighbours of agro-industrial farms and enterprises.

The study team interviewed financial institutions, policy makers, decision makers in energy, agricultural and waste issues as well as NGOs, enterprises and a wide range of industrial associations linked to the agro-value chain, as stakeholders in the biogas sector. Each of them has a role to play in the development of the agro-industrial biogas market.

The study team and GIZ defined the following categories of stakeholders:

1. Key Informants
2. Service Providers
    a. Technical Service Providers
    b. Financial Service Providers
3. Clients
    a. Owners of existing biogas plants
    b. Potential biogas clients and their associations

For each category of stakeholders an interview guideline (questionnaire outline) was elaborated for specific data collection.

The following chapters presents an analysis of the perspectives, perceptions and opinions of 12 Key Informants, and 9 out of 14 service providers, both financial and technical, 30 owners and operators of agro-industrial biogas systems, and 25 potential biogas clients.

6.1 NATIONAL KEY ACTORS IN THE ENERGY AND AGRICULTURAL SECTORS

Bangladesh has substantial theoretical potential for the generation of renewable energy. Resource assessments indicate that Bangladesh could realize annually over 6,000 GWh from renewable energies. The Government has ambitious targets for renewable development, and a robust and active private sector has substantial experience increasing access of off-grid solutions to commercial and residential customers.

The study team could meet the following key actors in the sectors of agriculture, energy and financing, and talk with them about their perspectives on the current and the future market for agro-industrial biogas systems:

1. Bangladesh Infrastructure Finance Fund Ltd. - BIFFL
2. Bangladesh Agricultural Research Council - BARC
3. Bangladesh Agricultural Research Institute - BARI
4. Directorate of Agricultural Extension – DAE
5. Department of Environment - DoE
6. Directorate of Livestock - DLS
7. Mutual Trust Bank Ltd. & Association of Bangladesh Bankers – MTB & ABB
8. Sher-e-Bangla Agricultural University - SAU
9. Trust Bank Limited - TBL
10. Bangladesh Energy Regulatory Commission - BERC
11. Bangladesh Environmental Research Foundation - BERF
12. Infrastructure Development Company Limited - IDCOL

6.1.1 ENERGY SITUATION

As reported in the interviews, the energy situation in Bangladesh is characterized by the fact that the demand for energy is higher than the current supply for any energy form – either electricity or natural gas. The use of fire wood is discouraged, and the supply of natural gas and CNG is diminishing. Only 3% of the population is enjoying natural gas connection which is limited to urban counterpart of the country. And electricity coverage is currently not extended as the electricity supplier is already now having troubles to meet the current demand.

For national electricity energy generation capacity, the GoB targets up to 23000 MW in 2020. Natural gas is still available, same as biomass rural households. But coal and LPG are imported; the same applies for nuclear power technology and nuclear raw material. The country has needs to reduce its dependence from any kind of fossil fuels – this is the common opinion of all interviewed key actors.

That's why all key actors also perceive the urgent need to increase investment in renewable energy technologies. They expect from SREDA a clear progress towards any of the renewable energies, not only for closing the demand-supply-gap, but also for sustainable economic development through job creation and less adverse environmental impacts.

6.1.2 POTENTIAL OF ALTERNATIVE OR RENEWABLE ENERGIES

The perception of the key stakeholders on the potential of alternative or renewable energies to cover the increasing demand for energy in Bangladesh corresponds to the GoB vision to increase the share of Renewable Energies up to 1 GW in 2020. However, until now the RE load is either too expensive, or requires too much land: a PV system with 10 MW needs about 14 ha, and land is an issue in Bangladesh.

The sector key actors see a great potential for renewable energy source, provided they are properly implemented. There are various sources of organic waste to produce biogas and biofuels. Hydropower generation is also one of the alternatives due to hundreds of rivers and wetlands in the country. Wind energy can also be used, particularly in the coastal and hilly areas. Solar roof top energy has a bright future in Bangladesh.

Moreover, Government and international donor agencies are showing interest in this sector. To date, 74% of the population has access to electricity (up from only about 20 percent in 1990). Electrification rates are highest in urban areas, where only about 1% lacks access to electricity. In rural areas, 34% still do not have electricity. Electrification rates (overall 72% in 2015) have improved in recent years because of rapid acceleration of grid connection to rural areas, coupled with the installation of solar home systems —since 2003, about 3.8 million solar home systems have been installed, benefiting about 20 million people.

6.1.3 FRAME CONDITIONS FOR FEASIBILITY OF RENEWABLE ENERGIES

Referring to the frame conditions for achieving feasibility of renewable energies, especially the financing institutions such as BIFFL and IDCOL, but also the private commercial banks are ready to support projects in both Renewable Energies (RE) and Energy Efficiency (EE). However, convincing projects with comprehensive business plans and favourable feed-in-grid tariffs as incentive for market development are still missing. No clear policy is in place to force utilities to buy RE from energy producers.

Besides the need for a review of the RE feed-in grid tariffs that should cover any type of RE, not only solar power, highly skilled personal is needed for the specific RE technologies esp. to transfer advanced biogas and bioenergy technologies to Bangladesh. In the clear view of the key actors, the frame conditions currently in place do not (yet) favour the increased application of RE & EE. An example is given for the feed-in-grid tariffs for RE: when sold to the grid, the energy producer receives USD cents 7.00 to 8.00; but as electricity customer he must pay USD cents 17.00, making feasibility of large scale RE-projects impossible.

Key stakeholders request a strong political will of the Government to create an enabling environment for RE development, to establish a power system portfolio by fuel diversification, to realize a low-carbon society by introducing a high-efficiency power supply which is low in GHG emissions, and to build an appropriate infrastructure for stable power supply. All this further requires a multi-sector coordination with efficient and effective mechanisms, and regulations to finally actively develop the national primary and renewable energy resources.

To achieve the vision of a middle-income country, and to reduce poverty through balanced socio-economic growth, large investment is needed to put in place environmentally sound innovations in the local contexts. Waste-to-Energy (WtE) projects, such as modern agro-industrial biogas systems are one huge opportunity for the country to tackle at the same time energy and climate change issues.

6.1.4 Energy potential of organic waste

The potential of 'organic waste' as local source for energy production is already known by most the key stakeholders in the sector. Most of them mentioned the need for more information to decision makers (public and private sector and investors) to increase research, investigation and installation of adequate systems for safe and efficient treatment and disposal of the abundant amounts. Organic waste could be converted into biogas, as it happens already in many countries. Investors from abroad (for example: Germany) should be invited for W2E projects. To increase the value of organic waste, both in urban and in rural settings, the fees for waste disposal should no longer be managed informally, but under enforced environmental regulations.

6.1.5 Barriers to market development of agro-industrial biogas technologies

Sector key actors identify as barriers to the market development of agro-industrial biogas technologies the facts that

- biogas-to power is not yet included in feed-in-grid tariffs (only solar, wind, hydro), neither for electricity nor for natural gas grid; therefore, business plans could only be based on captive power generation and not on revenues from power sale;
- no effective subsidies are provided to large-scale agro-industrial biogas systems, mostly loans at interests which result in additional burden to the system owner;
- the technology level – based on the household digester models, is obviously not suitable for large-scale systems (blockages and clogging due to sediments in poultry droppings fed digesters; no measuring devices installed to proof service hours of generators and other equipment, and amount of biogas and kW produced
- no tariffs are in place for electricity produced through RE
- no incentives for RE use are established, neither for the consumers nor for the producers of clean energy

When asked to evaluate the availability of raw material for energy generation through biogas technology, the sector key stakeholders admitted that "suitable materials are available everywhere”, but that policy and decision makers are not yet trained to see the potential of biogas technology; therefore, they limit its application to poultry and cattle farms only.

Residues of crops, fruits and vegetables, molasses and organic waste from plant and meat processing industries could provide sufficient raw material for large scale power production, although in some cases and places it may be difficult to collect them in a viable manner.

6.1.6 INCENTIVES FOR WASTE TREATMENT IN AGRO-INDUSTRIES

Incentives for waste treatment in agro-industries - including farms, slaughterhouses, food & beverage producers, sugar industry, are required but not (yet) practiced. Information need to be shared with private sector (waste producers); waste treatment should be mandatory for every factory/ industry in the sector. Waste treatment is a major headache for agro- industries as it can contaminate the inner and outer factory environment. Dumping is also problematic; therefore, if wastes are recycled in bulk amount to be converted into energy, this will motivate factories to invest in environmental sound systems.

6.1.7 ENERGY NEEDS OF THE AGRO-INDUSTRY

Although the energy needs of the agro-industries - including farms, slaughterhouses, food & beverage producers, sugar industry, are well known, the entrepreneurs do not want to take any risk; and obviously the in Bangladesh implemented biogas technology is not yet successful in presenting its potential

Energy need of agro-industries is not met by the current power supply. Most of the companies have their own electricity generating systems that are not much cost effective. Load shedding in Bangladesh has added another dimension to the problem.

6.1.8 POTENTIAL OF BIO-METHANE (CBG) AS VEHICLE FUEL

The information level on the potential of compressed biomethane gas (CBG) as vehicle fuel is low; only few of the key stakeholders in the sector are aware of this technology. Others call it a “revolution” for a green environment with a high potential to be accepted by the public due to substrate flexibility. There is probably a lot of potential, but the upfront costs are expected to be high.

6.1.9 Upgrading of biogas for feed-in natural gas grid

Upgrading of biogas for feed-in natural gas grid is currently not well practiced in the country, because “currently we do not see the technology work; but funding would be available it it’s a proven technology”.

Stakeholders emphasized that this kind of technology is urgently needed. Feeding biogas in the natural gas grid is a new challenge for grid operators as it requires new skills for balancing production and demand, and for ensuring safety for the customers. Grid operators are therefore encouraged to develop smart gas grids and be involved in gas quality monitoring as well as in setting up specifications and standards to enable the use of the natural gas grid as the most energy efficient and environmentally friendly way to transmit renewable gases.

6.1.10 Bottling biogas

The technology for bottling upgraded biogas is not yet practiced – only piloted - in Bangladesh, and sector key stakeholders have different opinions about its market potential. While some doubt that it could have an opportunity to gain the market, and they prefer to feed upgraded biogas into the natural gas grid. Others see a high potential for Compressed Bio-Methane not only for vehicle fuel, and they would like to see the GoB to encourage its introduction with incentives for local gas bottling companies. Yet others claim that they have never heard about it, but value already the idea as a good and think-worthy information, which could provide an opportunity for medium sized agro-industrial biogas plants to generate revenues from otherwise unused biogas.

6.1.11 Bio-slurry as soil improver

Bio-slurry as soil improver is very important for the sector stakeholders, esp. for those in financing institutions. According to them, business plans for agro-industrial biogas plants should always put clear emphasis on the slurry management. If proper caution is applied, bio-slurry is very much needed for increasing the organic content of soil. Some stakeholders emphasize that slurry from cow manure can be used as fertilizer and to feed fishes; hence improve significantly rural income. But slurry from poultry droppings is said to have toxic effects and demands to be treated properly before disposal. The current practice is to dump it indiscriminately exposed to the environment. Therefore, to realize the real potential of agro-industrial biogas plants, the consideration of appropriate and safe slurry treatment and final discharge needs further to be explored by Bangladesh's anaerobic digestion experts.

6.2 LEGAL REGULATIONS RELATED TO AGRO-INDUSTRIAL BIOGAS MARKET

Licenses, permissions, laws and regulations related to the agro-industrial biogas market do not yet really exist, because GoB does not see yet a relevant potential for biogas at another level than household application. Although there is a structured process for standardization of organic fertilizer through composting, bio-slurry as a by-product from the generation of biogas as renewable energy is only recently considered in the Draft National Manure Policy from December 2015.

Environmental clearance for the construction and operation of agro-industrial biogas plants should be obtained according to the Environment Conservation Act 1995, and the related rules in place since 1997. Stakeholders request that laws and regulations must be user friendly for the creation of a flourishing biogas sector, also to achieve a sustainable growth of the sector.

Other policies, which could enhance the economic feasibility of any agro-industrial biogas plant are

- Private Sector Power Generation Policy (1996), which intends to attract private sector investments in the energy sector to meet the sector's growth targets
- Renewable Energy Policy of Bangladesh (2008): the targets for the share of renewable energy in the national energy mix constitutes 5% of total generation by 2015 and 10% by 2020. The GoB is committed to facilitating public and private sector RE investments. By the RE-policy, GoB considers to scale up RE contributions to electricity and heat energy, and to substitute indigenous non-renewable energy supplies by RE.

Sector stakeholders expressed a strong interest to have a legal framework in place to create an enabling and supportive environment to facilitate RE use at every level of energy usage. The population in general should be encouraged to use efficient and environmentally-friendly energy.

6.3 INVESTMENT LIMITS

Limits for investment (own capital and loan) have been set by Bangladesh Bank. Project proponents should have at least 20% of own capital, and should proof their capacity to run the project successfully. A comprehensive business plan is requested which shows that the technology has its market. Land is the biggest issue for RE projects. Economic analysis is usually done during field efficiency trial for standardization process. Stakeholders recommend that investment of agro-industrial biogas projects should be provided by a maximum of 30% by own capital and 70% by loan (best would be from a governmental bank). Financial institutions underline that often the business plans for agro-industrial biogas projects lack consistency and a realistic view on the potential of the selected technology. And that often the costs of operation and maintenance are not included in the economic calculations, or economic perspectives are too optimistic.

6.3.1 SUBSIDIES

The sector requests the same subsidies as they are given to the fossil fuel sector. Government should offer tax exemption for equipment procurement and installation of renewable energy projects, or exemptions for customs and duties in the case components of agro-industrial biogas systems are imported for technology transfer. To date, neither subsidies or nor any other incentives are provided to agro-industrial biogas projects. If a PV provides at least 10MW, then GoB should decide if this project receives any kind of subsidy. There is a facility of tax exemptions for solar panels, but not any similar facility is introduced until now for agro-industrial biogas technologies. Financing organizations like IDCOL and BIFFL would be ready for financing grants to lower the cost of capital of the project sponsors and to encourage the development in this sector. In addition, interest rates for agro-industrial biogas projects should be as low as possible to push sector development.

6.3.2 ALTERNATIVE FINANCING MECHANISMS

Alternative financing mechanisms for agro-industrial biogas projects – such as Clean Development Mechanism (CDM), are not yet practiced, perhaps also because the current international price of CERs/ Carbon credits is very low. However, if a project developer would include CDM or any other alternative financing mechanism in his business plan, project financiers would be open-minded enough to check if the proposed financing mechanism could cover at least the 20% own capital fraction of the total investment sum.

Sector key stakeholders underline that alternative financing mechanisms could enhance the marketing of the agro-industrial biogas technologies. There exist globally already an innovative variety for project financing, but in Bangladesh most of them are not yet introduced. While the idea of micro-financing started in Bangladesh for a specific project or group of project sponsors, nowadays other mechanisms are looked for – such as the Joint Crediting Mechanism (JCM), introduced by Japan. According to the point of views of the key stakeholders, any suitable financing scheme could bring benefit both in terms of finance and environment to the sector and as such also to sustainable development. They even stressed that CDM should play a stronger role, as it could stimulate sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction or limitation targets.

As the Kyoto Protocol, in its present form, expired at the end of 2015, the funding mechanisms created under the Protocol are also ended. These mechanisms were also criticized for the heavy bureaucratic burden on the project developer and implementer in terms of setting baselines, monitoring and verifying impacts. To reduce transaction costs, a replacement climate financing mechanism, the sector based Nationally Appropriate Mitigation Actions (NAMA) approach, has been designed to allocate financing to much larger programmes, rather than individual projects, and with a less stringent methodology for monitoring results.

The goal of such an organic waste NAMA is to transform Bangladesh's organic waste sector by creating greater certainty for investments in organic waste management projects that divert agro-industrial waste, faecal sludge, and sorted organic waste before landfill disposal towards more productive uses. Diversion avoids methane emissions while promoting sustainable economic growth and improving the living conditions of recyclers/ sorters/ collectors.

The GoB should propose, among other initiatives, to reform agro-industrial and municipal waste tariff regulations (gate fees) so that diverting organic waste for alternative uses such as combined waste-to-energy (biogas) and post-composting plants can compete economically with landfill disposal. The proposed financial mechanism is geared towards building in-country experience with integrated organic waste management technologies.

The GoB should propose the creation of a national revolving NAMA equity fund to overcome investors' hesitation to invest due to a lack of familiarity with modern biogas as key technology and compost transforming processes. The equity fund would contribute equity capital on a concessional basis to help build waste treatment facilities on a municipal level, contributing to projects in multiple cities and attracting other equity and debt investors to finance the facilities.

Repayment of equity from project developers may remain in the fund and be available for equity investments in future projects. Over time, the contribution from the NAMA equity fund may be reduced as investors become more knowledgeable about the waste treatment technology and the associated operational and financial risks, with the eventual goal of not needing concessional support for integrated waste management projects.

6.4 RELIABLE SERVICE PROVIDERS

6.4.1 TECHNOLOGY PROVIDERS

Asked for their criteria for reliable technology providers in the agro-industrial biogas sector, some key informants took quite a critical look on those enterprises: they evaluate them as not as successful as expected, because of failures related to three critical questions: (1.) What is their (technical, marketing, service) capacity? (2.) At which price do they sell the technology? and (3.) Is this economic viable for an enterprise to retain the trained people?

Officially there are no professional criteria for biogas technology providers, but most of the key stakeholders stressed that the technology provider must be a specialist, must work profitable and really devoted; must be innovative, non-corrupted, and committed to sustainability. Currently, observers within the sector notice lack of efficiency, capacity and commitment. The technology offered by the service providers should be appropriate to the context of Bangladesh, and should be implemented applying professional standards. Some key stakeholders have set up their own criteria and specific guidelines to be followed, but these refer only to household biogas plants.

6.4.2 ENERGY PROVIDERS

For sector key stakeholders, reliable energy providers should be skilled, knowledgeable and capable, organized, efficient, non-corrupt and honest, and a specialist in the sector. These criteria will gain importance for a stable market development especially for biogas-to-power systems, or biogas-feed-in into the natural gas grid.

6.4.3 FERTILIZER PROVIDERS

Concerning criteria for reliable fertilizer providers, sector key stakeholders put first the need for proper processing of bio-slurry to achieve that the actual organic matter from the medium and large scale biogas plants could substitute at least 1% of imported fertilizer, these only based on Nitrogen - if applied in liquid form in crop production. Fertilizer providers should adhere to the licensing process from DAE, and their product must be approved by the authorities, like any other organic fertilizer produce. As advance technology users, they should be highly qualified persons, well established business providers with a strong ability to reach farmers, and gaining reasonable profits through ell established distribution channels.

6.5 IMPACTS

6.5.1 IMPACTS ON CLIMATE AND ENVIRONMENT

The World Risk Report ranks Bangladesh as the fifth most vulnerable country to climate change, despite its negligible carbon footprint. As a low-lying country with many rivers, Bangladesh has a very high flood risk, both due to monsoons and sea-level rise. The impacts of agro-industrial biogas systems on greenhouse gas emission reduction, and climate change mitigation are estimated by the key informants in the sector as currently very low, as there is no policy for biogas-to-power or natural gas grid connection. Nevertheless, agro industrial biogas systems do have a high potential for GHG emission reduction, and their positive impact on the environment and the climate could be tremendous. Sector stakeholders therefore opt for more agro-industrial biogas systems and a policy change to allow feed-in-grid technologies for biogas-to-power plants.

Rising temperatures have already begun to shorten the life cycle of rice; reducing yields. Low crop production could increase poverty up to 15 percent by 2030. Higher water levels could lead to higher incidence of waterborne disease, such as cholera, and result in forced migration due to flooding. In addition, the Climate Change Vulnerability Index rates Dhaka as one of the five most climate-vulnerable cities in the world. Bangladesh addresses climate change issues through the Bangladesh Climate Change Strategy and Action Plan, which is implemented through the donor-funded Bangladesh Climate Change Resilience Fund. The impacts of agro-industrial biogas systems on ecology and environment such as reduction of deforestation, environment pollution, ground and surface water bodies, and health hazards, are recognized within the sector, but is missing appreciation from outside the sector. Key stakeholders highlight that within the next 5 years, manure processing and marketing will have to improve significantly to make the agro-industrial biogas value chain visible to everybody. They recommend that GoB should buy in the business to support the reduction of negative environmental impacts, to promote ecological balancing and preventing hazards. Agro-industrial biogas systems could help to increasing the fish species, maintaining the water ecosystems, reducing diseases, and in general improving environmental health.

6.5.2 IMPACTS ON ECONOMY

Theoretically the socio-economic impacts on local and national economy: job creation, improved food production and food security are numerous. Besides job creation against unemployment (if the biogas industry turns out to be big and sustainable) the project sponsors also bear the responsibility to employ and train manpower. Bio fertilizer from slurry can lead to improved food production and food security. In macroeconomic level, local job opportunity can reduce the migration of rural people to cities, hence resulting in proper distribution of work force, and development of small and medium entrepreneurs. Key stakeholders unanimously confirmed that agro-industrial biogas systems contribute essentially to local and national economy through job creation and improved food production to achieve food security.

6.6 MARKETING STRATEGY PROPOSALS

Among the sector key informants, marketing ideas for agro-industrial biogas technologies and their end products energy (CBG, biogas, electricity) and organic soil improver are numerous, but still need to be elaborated in detail for achieving sustainable market growth. These ideas relate to

1. Waste-to-fertilizer and energy:
    a. Focusing on bio-slurry as a very good soil improver.
    b. Focusing on biogas as vehicle fuel- it's now being used as a substitute of natural gas.
    c. Focusing on biogas to generate power – as distributed electricity in a meaning on mini grids.
    d. Focusing on biogas as cooking fuel.

2. Zero-Emission
3. Water recycling esp. for irrigation water
4. Ecological branding for marketing of both the technology, the investor and system operator

However, there is neither a systematic social nor commercial marketing strategy in place. Key informants regret that also the entrepreneurs in the sector have no marketing strategies for agro-industrial biogas technologies and their end products. Therefore, some recommend a geographic segmentation, to invest in areas with higher energy demand and with lower availability of formal energy sources. Others conclude that promotional activities should focus on environmental and climate impacts, cooking gas in rural environment and the sustainability of renewable energy

Key Informants named other relevant national stakeholders for sustainable market development for agro-industrial biogas technologies, such as DAE, DoE, Centre of Energy Studies (CES), BUET, DLS, DOF and related Ministries. NGOs, Universities, and private companies, should be involved, including technical and financial service providers, owners of commercial poultry and cattle farms, equipment suppliers. The key stakeholders in the sector regret that often actors in the same as well as in other sectors are 'resistant to learn, although they lack a lot of capacity to accomplish their roles.

Others observe that both, the risk of technology failure and the cost of funding hinder currently the smooth dissemination of agro-industrial biogas technologies in the country. They recommend to project developers to seek also support from development agencies, even if these would probably give only little support. And they recommend esp. to technical service providers to improve their capacities, because ‘last of all it is an excellent idea’.

7. TECHNOLOGY PROVIDERS

The following technology providers are pushing the market development for agro-industrial biogas systems (situation at early 2016):

1. Biogas Technology Consulting Services Ltd (BTCSL) - *started in 2010; since then they are engaged for construction of biogas digesters (small size, medium size & large size). BTCSL provides training for users and other service providers, engineers throughout the country. So far BTCSL have constructed more than 1500 biogas plants in category E, D, and C. They are also engaged in bio-fertilizer processing, sorted municipal solid waste management (MSW), through biogas technology with the collaboration of Waste Concern, a renowned NGO in Bangladesh.*
2. Advance Engineering - *constructed more than 800 small and medium biogas digesters throughout the country since 2002. They are working with R&D of biogas technology with GIZ, IDCOL and others. As partner organization of IDCOL they are engaged in manufacturing biogas appliances and improved cook stoves (ICS) since 2006.*
3. Nirapod Engineering – *they are constructing both small and medium sized biogas plants for cooking and generation of electricity throughout the country. As a manufacturing partner organization of IDCOL they are providing biogas appliances.*
4. Advanced Animal Science Company Ltd. - *experienced in construction of biogas plants and the installation of biogas appliances including power generator. They are importing biogas run generators, solid-liquid-separators, and other biogas appliances, and prefabricated digester models from China.*
5. Hossain Biogas Agency - *partner organization of both GIZ and IDCOL, experienced in the construction of small and medium size biogas plants.*
6. Sabbir Engineering - *construction firm for small and medium size biogas plants. They constructed more than 1500 biogas plants in different districts in Bangladesh. They are working with BCSIR since 1997.*
7. Kamrul Biogas Agency- *an experienced agency having constructed more than 5,000 biogas plants throughout Bangladesh. They are working with GIZ, IDCOL & BCSIR as partner organization.*

8. Bengal Biogas Renewable Energy Ltd - *a LCPO of IDCOL for both biogas and solar installations, entering the agro-industrial biogas sector in 2015.*
9. Chicks & Feeds Ltd. - *a state of the art Agro-Industrial solution provider. From the very beginning of the company, the strategy was to deal with limited customer and ensure them professional service and satisfaction. The scope of service embraces planning through project implementation. Some global companies joint Chicks & Feeds LTD as strategic partners to promote their products in Bangladesh and to introduce in the sector modern technology including modern CSTR biogas technology, at reasonable investment.*
10. RDA - Bogra - *The Rural Development Academy (RDA - Bogra was established in 1974 as a specialized Rural Development Institution for training, research and action research. RDA developed and implemented 36 community based biogas plants of 60m^3 gas production each, in different districts for generation of electricity, CBG and bio-fertilizer. Bio-slurry obtained from community biogas plants is processed through sun drying and later used by the community people on their own land; marketing rate is BDT 5.00/kg. Biogas is used for cooking, generation of electricity, drinking water supply to the community and partially supplied to the RDA CBG station at RDA campus with a storage capacity of 400m^3.*
11. Masum Biogas - *one of the leading service provider for design and construction of more than 60 medium sized commercial biogas plants. They have skilled engineers, masons, and technicians working across the country.*
12. Khokon Das- *enterprise of an experienced and inventive biogas technician, currently setting up biogas upgrading and compressing station at Chittagong; test supply of CBG started to three-wheelers, and for bottling, but the project still needs technical fine-tuning to be technological and economical successful/*
13. Rahman Renewable Energies RRE - *owner is working for 19 years in the biogas sector: started 1996 with BCSIR & Practical Action; 2006 created a company and joined NDBMP; 2007 also working for GIZ & IFC program. Company's mission includes dissemination of biogas technology as renewable energy, both domestic and agro-industrial. The company participates in further RE programs such as improved cook stoves, and constructed to date 455 domestic biogas plants and 24 commercial biogas plants (size 6m^3- 45m^3), is currently developing membrane covered lagoon biogas plants.*

14. Seed Bangla Agro Ltd. (SBAL) - *leading service provider for design, construction, maintenance and operation of agro-industrial biogas plants. They constructed more than 100 medium to large biogas plants. They have trained engineers, technicians and masons for construction of biogas plants. They are also licenced for processing and marketing of bio-fertilizers from bio slurry.*

In general, technology service providers identify themselves as business houses which run on profit or loss. They will only undertake any contract if there is a party to buy their service. Thus, all their activities must be based on a business model to be successful.

7.1 CAPACITY NEEDS ASSESSMENT OF TECHNOLOGY PROVIDERS

In intensive dialogues, 9 of the 14 leading technology providers for agro-industrial biogas systems in Bangladesh talked individually several times to the study team about their own perceptions of their level of skills, knowledge, and abilities, as well as their professional gaps and needs for improvements.

7.1.1 ENTREPRENEURIAL STRENGTHS

Rahman Renewable Energies RRE: 15 – 35 people under contract, with academic engineering and scientific background, and technicians; about 100 masons trained from IDCOL, GIZ, IFC; construction of household and commercial biogas plants, mostly at poultry farms.

Seed Bangla Agro Ltd. SBAL: Established in 2010, while its inception into the alternative energy market dates to 2006 under the title of Seed Bangla Foundation. Key strengths: (1) efficient and experienced management team; (2) well connected with national and international organizations; (3) trained and experienced engineering team consisting of academic trained civil, structural, mechanical and electrical engineers; (4) IDCOL & GIZ trained masonry group of around 100 masons; (5) more than 300 support masons on contract; (6) country wide sales and marketing network for fertilizer.

BTCSL: Skilled manpower for designing, constructing, operation, and maintenance of agro-industrial biogas plants. The company conducts training workshops on biogas technology. Has experienced engineers and masons for biogas plant construction, and experiences on bio-slurry management and processing.

RDA Bogra: Skilled manpower for designing, constructing, repairing and maintenance of biogas plants. Resource persons for preparing training manuals. Training course module including training materials development. Availability of training venue, class rooms, auditorium, accommodation facilities for 600 persons at a time including cafeteria. Practical grounds: Dairy unit, poultry unit, bio-slurry collection, processing, drying and packaging floor.

Masum Biogas: 10 skilled and 10 semi-skilled staff in biogas designing and construction, repairing, maintenance of biogas plants and office management.

Advanced Animal Science (AASc): experienced in hydraulic pressure biogas systems and convenient construction solutions; they have introduced a new type of biogas plant featuring easy operation, easy maintenance, fast initial gas production and bag gasholder. The digester is sealed with water.

Chicks & Feeds (C&F): State of Art technical team with many university-trained bachelor and master engineers: mechanical (D1&2), electrical (D2), civil engineer (D1), divided in 2 departments: (1) for new projects; (2) For customer care; in 2007-2015 national partner of HEEEC, China, since 2016 for the German biogas company BEKON.

7.1.2 BUSINESS CHALLENGES OR DEFICITS

The most pressing challenge for any service provider in the agro-industrial biogas sector in Bangladesh is the question how to handle the bio-slurry from large-scale poultry dropping fed biogas plants. All solutions which have been tried so far were not successful. The customers are getting angry and business opportunities are vanishing. Therefore, the deficits are explicitly listed by the companies: they have no connection to international service providers who would be in the position to provide solutions to this challenge. As was also mentioned in the workshops, any technology provider should give a total solution instead of only a biogas plant.

Some of the technology companies are aware that the plant model they are constructing is not appropriate to solve the need of their customers, who must solve environmental problems with huge amounts or poultry droppings. One deficit of the sector according to them is the fact that no in-depth detailed training on latest international technology developments is provided in Bangladesh, and sector stakeholders continue to promote medium and large fixed dome biogas plants although the problems of this model for large scale poultry farms are well-known. Technology service providers in Bangladesh are aware that international biogas markets provide different models, and other poultry dropping management approaches based on co-fermentation biogas systems.

Furthermore, in visits at medium and large scale biogas plants and in talks with owners and service providers across the country, the interest in converting the slurry into profitable compost fertilizer became obvious. However, also linked to bio-slurry are the challenges of transportation and marketing: the deficit list contains insufficient storage space, drying, grinding and packaging devices (machines) and bags. Some of the challenges and deficits could probably be solved by training. But issues like indifferent mentality towards organic waste management, careless transportation needs more legislative approaches.

Deficits in the sector identified by the same service providers relate also to the not existing measuring devices at agro-industrial biogas systems, which causes business challenges because remote monitoring of biogas production and climate friendly use for external financing is impossible.

Technology service providers expected from BBDF to offer services to both clients and service providers for improved designs so that slurry could be managed and converted into a profitable product.

7.1.3 IMPROVING ORGANIZATIONAL STRENGTHS

The interviewed service providers are highly interested to participate in specific design training to understand, develop and implement other designs than the well-known up-scaled fixed dome model. They emphasized that even their organizational strength cannot solve the current problems they encounter. Trying to do some research for solutions to the bio-slurry post-treatment and management problems and contacting and visiting Chinese companies couldn't derive any solution

This is due to the fact, that Bangladesh is one of the few countries where poultry droppings are used as mono-feedstock in biogas plants without adding other carbon rich organic matter to balance the high level of nitrogen contained in poultry droppings. Therefore, poultry droppings mono-fed plants need a high fresh water consumption to achieve the required dilution for the uric acid content.

> Nitrogen is excreted from birds in the form of uric acid and organic nitrogen. Conversion of uric acid to ammonia requires the enzyme, urease, which is excreted in animal faeces. This conversion occurs rapidly, often within a few days. The breakdown of complex organic nitrogen forms in faeces occurs more slowly (within months or years). In both cases, the nitrogen is converted to either ammonium (NH4 +) under acidic or neutral pH conditions or ammonia (NH3) at higher pH levels.

Some service providers see their strength in their customer relations: technical expert teams provide for 24h service on call. They provide training for customers, addressing the problems with competent technical experts and arranging advanced training courses for workers and plant owners. However, current technical service providers in the Bangladesh biogas sector do not see themselves in the position to implement up-to-date technologies. Some of them therefore request training sessions in Bangladesh or exposure visits and training abroad.

Other service providers hire international experts for technical support, or train their technical staff in new technologies through cooperation agreements with foreign biogas enterprises.

Service providers emphasize that efforts need to be made to identify other technologies to expand the ambit of technology service providers.

7.1.4 TRAINING MANDATED BY THE GOVERNMENT

There is no governmental mandate to which the service provider must comply except environmental clearance. But the technology service providers mostly are not sure if there are any mandatory trainings.

7.1.5 PERCEIVED FORCES FOR MARKET DEVELOPMENT

While some service providers perceive an increasing demand for biogas – because natural gas reserves are diminishing, others are more pessimistic and do not see at present any supporting forces for a future agro-industrial market. In the opinion of other service providers, a strong coordination of different governmental departments (agriculture, livestock, food processing) could support the efforts for agro-industrial biogas market development.

7.1.6 OPPORTUNITIES FROM NEW TECHNOLOGIES AND TRAINING

With latest technology information and knowledge on biogas purposes others than cooking fuel and power generation, with further contacts and marketing support the agro-industrial biogas service providers undoubtedly will be enabled to gain a competitive edge in the market. The success of processing organic agricultural and municipal organic wastes also depends on the market for recycled products. That's why service providers also emphasize their need for capacity building activities in marketing strategies and actions.

It is expected by technology service providers that BBDF with its local and international connections and its R&D activities may act as a vehicle for introduction of new technologies and giving all sorts of training supported by GIZ and SREDA.

7.2 PLANNING FOR MARKET EXPANSION

7.2.1 CHALLENGES AND CHANGES

For analysing the capability of service providers to deal with future challenges and changes in the biogas sector, the study team wanted to know, how the service providers would handle challenges, which are expected to change the sector. However, the service providers are very much focusing on how to solve current problems with poultry droppings fed biogas plants.

Generally, they do not see international competition in the biogas market in Bangladesh, because they are eager to learn from international companies. They are strongly interested to sign international cooperation agreements for innovating the biogas sector in Bangladesh. The limitation of being only capable to design biogas systems for the treatment of one single type of raw material (either chicken dung or cow dung or food waste or …), and considering only wet fermentation as anaerobic digestion technology pushes a relevant number of them to look for opportunities to broaden their knowledge, for example on co-fermentation technologies and on dry fermentation technology. This capacity development could be realized through training courses, exposure visits, international conferences and workshops, and other means.

Some providers are quite realistic formulating their perception of market development as follows: if the current problems esp. with sediments in, and slurry from medium and larger sized poultry farm biogas systems could not be solved within a short delay from now, there would be no market development for agro-industrial biogas plants at all. In summary: the reduction of water input, reliable technologies for and convenient operation and maintenance of agro-industrial biogas systems (incl. model change, state-of-art process control), and feasible handling and marketing of slurry (incl. a smart licensing system for organic fertilizer) are the big topics for which the technology providers request capacity building for sustainable market development and support from GoB through appropriate policies.

7.2.2 COST-BENEFIT ANALYSIS - GENERAL OPINIONS

The same technology providers, who are building the biogas systems, estimate that about 60% of the plants are not working as per expectation and promises to the clients. Besides unsolved technical issues, the management of commercial plants is not up to to-date business standards. In their opinion, the current situation needs to be overcome as soon as possible and with high quality, because otherwise there will be no more interest from potential customers and the entire biogas sector will suffer.

On the other hand, the untreated or incompletely treated disposal of livestock farm and agro-industrial residues leads to pollution of the environment and release of huge amounts of greenhouse gases, and the investment in waste-to-energy systems should be calculated against these climate, environment and public health destroying effects.

Better service to biogas customers through training and engaging entrepreneurs living in the location of the agro-industrial biogas plants could yield higher output throughout the service life of a biogas systems. Investment in capacity building for decentralized market development will bring more benefits for biogas marketing in general.

7.2.3 Enabling factors for successful participation in the development of a commercial agro-industrial biogas market

Here again, the service providers emphasized the need for modernization of the sector through updated training. Transfer of state-of-art technology and business models for agro-industrial biogas systems, incl. bioslurry processing and marketing, and biogas upgrading to bio-methane and compressed biogas are expected to enable the service providers to provide better services to their customers. A Practitioners' Handbook for design, operation and maintenance of 'new' medium and large anaerobic digestion technology – appropriate for Bangladesh - should accompany the refurbishing of the biogas sector.

Educating and creating awareness among people is underlined as necessary. It was mentioned to do this using social media for extensive circulation of news about biogas to ensure that Governmental officials, banks and the public know about the benefits of biogas not only as cooking fuel especially in rural areas, but also in industrial applications, because natural gas usages recedes from its present usages patterns.

7.2.3.1 Cost-Effectiveness

High rates of staff turnover make it necessary to repeat often training-on-job sessions. If staff could be paid better, skilled masons would stay in the business. Going closer to the customers by including local laymen and enterprises, all farms and market places, municipal waste, agriculture waste could be considered as viable for the installation of a large biogas system, which could help to strengthen the national power grid. To achieve this, awareness on biogas potentials should be raised among agro-business elites and the private sector to create interest for investment opportunities.

7.2.3.2 Regulatory Framework

Currently there are no laws, rules or regulations requiring a solution to environmental pollution with organics, although any agro-industrial enterprise must have an environmental clearance.

Now-a-days the Department of Environment is very particular in issuing permission to any project which does not depict a waste management situation. This should be forcing technology service providers to upgrade their offers towards environmental sound systems. Nevertheless, most of service providers do not yet feel any pressure from national and sector authorities to find solutions to the environmental and climate challenges caused by manure and slurry challenges, and other agro-industrial residues. If there would be a law and enforcement of the law saying that organic residues should be managed safely and violation of that will be a punishable offence the situation would change, and Anaerobic Digestion (AD) market will grow.

All over the world financiers raise the issue of environmental and social concerns. Thus, service providers propose that funds should be available in Bangladesh for compliance with environmental and social requirements before granting any loans to an agro-industrial biogas project.

7.2.3.3 CUSTOMERS' INFLUENCE

As the technology providers know only one plant model (exception: Paragon – Chicks & Feeds CSTR model) no differences in plant specification are possible. The customers themselves are not well informed about the broad range of biogas technologies. They want value for money, affordable loans and reliable captive electricity generation; a lot of potential benefits from the systems are not well known to the customers, and they cannot find different technology and management proposals in the country.

8. RESEARCH INSTITUTES

8.1 SUMMARY

Investigation among Bangladesh research institutes revealed that – beside one international supported short training workshop which took place in early 2016 at BAU Mymensingh - no institute is conducting any regular technical or market research and development activities for modern agro-industrial large size biogas systems; beside many bio-slurry application research, no research is conducted on state-of-art process control and equipment, or on bio-slurry post-treatment optimization. Therefore, no further formal interviews were conducted with these institutes.

With a burgeoning population, the pressure on limited natural resources is very high. As a result, an effective strategy for sustainable environment critically depends on how Bangladesh manages its natural resources. To address that objective, the following activities are considered under the 7th Five Years Plan (FYP) to ensure better management of natural resources. Under Issues 1: Protection of rural landscape and improving environment, the following programme is mentioned: Expanding solar supply and supporting programmes on composting & biogas production from cow dung poultry droppings and organic wastes through piloting and promotional activities. It is also clearly mentioned that GoB will support researchers on efficient means to harness the power of wind, biomass and biogas, along with other sources, that will not only be cost-effective and accessible, but will also generate employment and drive growth.

Since recently, Universities could get a grant for introducing new technologies and launching pilot plants under the World Bank supported Higher Education Quality Enhancement Project. It is suggested that BBDF should initiate a program with interested universities to introduce courses and training to popularize biogas technology education.

8.2 INSTITUTE OF FUEL RESEARCH AND DEVELOPMENT (IFRD), BCSIR

Although the Institute of Fuel Research and Development (IFRD) was established in 1977 as a unit of Bangladesh Council of Scientific and Industrial Research (BCSIR), and counts with highly qualified staff, research & development for biogas plants is limited to household digesters. As one of the Governmental research institutes in the country, IFRD has developed and patented a fixed dome model made of brick cement, and is now investigating the performance of prefabricated fibre glass digesters. They are well able to work in the new AD sector.

9. OTHER POTENTIAL SERVICE PROVIDERS IN THE AGRO-INDUSTRIAL BIOGAS BUSINESS

9.1 CERTIFIERS OF DESIGN, MATERIAL AND SERVICE PROVIDERS

i. IDCOL- provides training on biogas technology to masons, service providers and engineers; their plants constructed with IDCOL grants and loans are certified by IDCOL. This is not only limited to domestic biogas plants, but is also applicable to agro-industrial plants if these AIBPs are financed under any international cooperation project. In addition, and it has been mentioned already, most of the AIBP in Bangladesh are just up-scaled fixed dome biogas plants, the same model which is constructed as domestic biogas plant.

ii. IFRD- Institute of Fuel Research and Development of BCSIR: provides training and certificates on household biogas technology and undertakes research in biogas technology.

iii. The Ministry of Youth provides training and certification for the trainees, but limited to domestic biogas plants.

Bangladesh based certifiers of design are only capable to certify the design of small size or domestic biogas plants. There is no certifier for large size / agro-industrial biogas plant, neither for design, nor for engineering, construction, and operation in the country. Only BBDF has in-house an international approach to certify the design, the quality of materials used and the service providers and may provide these services if demanded by any stakeholder. Financing bodies in Bangladesh need to be aware that any improperly designed unit could lead to an engineering and environmental disaster.

9.2 ORGANIC FERTILIZER PRODUCERS

i. Mazim group - processing and producing bio-fertilizer from fresh cow dung, poultry litter and bio-slurry; nowadays they are not using bio-slurry but press-mud from sugar mill, cotton wastes, ash, saw dust.

ii. Seed Bangla – processing and producing bio-fertilizer from bio-slurry for marketing. Although clients complain that they encounter serious problems with bio-slurry management, Seed Bangla is seriously searching for advanced and appropriate solutions.
iii. Waste Concern - actively engaged in management and production of organic fertilizer from Municipal Solid Organic Waste (MSW).
iv. Nandigram Kazi Poultry Farm - processing and producing bio fertilizer from poultry litter.
v. RASH Agro Enterprise- processing and producing bio-fertilizer from cow dung, bio-slurry, poultry litter, press-mud of sugar mills, ash, saw dust, molasses and Trichoderma (fungal inoculum). They are also producing bio-pesticides from indigenous plant extracts (alkaloid), biological wood preservative and biological plant growth promoter incorporated with Trichoderma (fungal inoculum).

Organic fertilizer processing and marketing are complex processes. This business is not yet well established in Bangladesh due to unclear legal framework, although more than 30 small and medium bio-fertilizer companies are operating in addition to the above mentioned.

9.3 Training Providers

i. IDCOL - provides training to masons, service providers and engineers, only on domestic biogas plants, but are intending to extend training to medium and large scale biogas plants in 2016.
ii. BBDF - Bangladesh Biogas Development Foundation- actively involved in providing consultancy services, conducting seminars / workshops and training on biogas technology
iii. GIZ - gives training on biogas technology to its partner organizations, masons and others for small and medium sized fixed dome biogas plants
iv. IFRD/BCSIR - two weeks training, both theoretical and practical, on design, construction, operation and maintenance of domestic biogas plants.
v. BAU – started 2016 with advanced training in modern biogas technology with DANIDA support.

Training providers are still too much focused on small and medium domestic fixed dome biogas plants. There is a pressing lack of experienced trainers for design, engineering, construction, operation and management of large size agro-industrial biogas plants.

9.4 EQUIPMENT PROVIDER

i. Chicks & Feeds - providing all kinds of imported biogas appliances for large size biogas plants
ii. Advanced Animal Science - providing all kinds of biogas appliances for household biogas plants
iii. Advance Engineering - providing all kinds of biogas appliances for household biogas plants
iv. Nirapod Engineering - providing all kinds of biogas appliances for household biogas plants

Bangladesh's biogas equipment providers – also some more than the above mentioned - are still concentrated on the domestic biogas sector. Only few providers deal with the required large scale equipment for large size agro-industrial biogas plants. As the market picks up more players will come into the field.

10. POTENTIAL BIOGAS CUSTOMERS

At least 25 professional associations, national and international NGOs, governmental organizations and private sector enterprises have been identified as potential customers for an improved agro-industrial biogas market. They could be included in information and marketing campaigns to provide the messages to their individual members or own target groups, this promoting the dissemination of agro-industrial biogas systems in the country to supply clean energy to all, and to improve soil fertility through the application of the well-prepared bio-slurry.

A specific case of agro-industrial biogas systems could be built up by the Bangladesh Sugar Industries: there are 15 sugar mills under Bangladesh Sugar and Food Industries Corporation (BSFIC). Each sugar mill produces about 30-40 tonnes pressed mud as waste per day and discharges 350-450 tonnes/day wastewater. Pressed mud is generally heaped up near the sugar mills and are sold to the people at a very nominal price for cooking purposes. The waste waters are entirely discharged untreated into the nearest canals and rivers. The energy content of these two waste streams remains practically unutilized, while their untreated discharge pollutes heavily the environment. Laboratory experimentally found that pressed mud could have the same energy potential as cow dung when used as raw material for biogas production. From these 15 sugar mills a total of 16,650m^3 biogas could be obtained only from the wastewater, which may generate daily 26,640kWh electricity, and produce about 90 tons of solid bio-fertilizer per day.

In the 7th Five Year Plan (2016-2020) from the GoB the Ministry of Industries has already published the target for the Bangladesh Sugar & Food Industries Corporation (BSFIC). This organization is committed towards the strengthening and sustaining of the production capacity of the existing sugar mills, to meet the local demand by producing white sugar from imported raw sugar, reduce dependency on private sector and stabilize the domestic market and benefit the consumers. BSFIC also aims to produce environment friendly organic Bio-fertilizers, Biogas that will reduce fuel consumption, increase sugar cane production and consider using molasses to produce alcohol/spirit.

The following table lists the potential agro-industrial biogas customers. The table also includes potential clients for power from biogas and the factories for organic fertilizer, to which dried bio-slurry could be sold as ingredient for the final marketable product.

1	Bangladesh Egg Producers Association	www.bpicc.poultry.com	Agriculture / Livestock	Potential for biogas
2	Bangladesh Export Processing Zone Association	www.epzbangladesh.org.bd	Agro-Processing	Potential to setup biogas plants
3	Bangladesh Frozen Foods Exporters Association	www.bffea.net	Agriculture/ Live stock	Potential for biogas
4	Bangladesh Fruits, Vegetables and Allied Products Exporters Association	bfvapea-association@yellow.com	Agriculture/ Live stock	Potential for biogas
5	Bangladesh Agro-Processor Association (BAPA)	www.bapabd.org	Agro-Processing	Potential for biogas from fruit waste
6	West Patiya Development Association	www.bangladesh-economy.org	Agriculture/ Live stock	Situated in Chittagong (CTG) Milk hub
7	Chittagong Hill Tracts Development Foundation/ UNDP	www.chtdf.org	Service Provider	Regional development body with the charter to develop potential sources of energy in the three regional districts of Chittagong hill tracks
8	Bangladesh Dairy Farm and Cattle Farm Association	https://bn-in.facebook.com/BangladeshDairyFarmAndCattleFarmAssocatation/	Agriculture/ Live stock	Dairy waste to biogas projects
9	Bangladesh Garment Manufacturers & Exporters Association (BGMEA)	www.bgmea.bd	Organic Waste/ Networking	Garment manufacturers association with potential to generate biogas from garment waste & wastewater
10	Bangladesh Poultry Industries Association	www.bangladeshpoultry.com	Agriculture/ Live stock	Biogas from poultry litter
11	Bangladesh Shrimp and Fish Foundation (BSFF)	www.shrimpfoundation.org	Agriculture/ Live stock	Potential for biogas
12	Bangladesh Sugar & Food Industries	www.bsfic.gov.bd	Consumption (Organic	Potential for biogas

	Group			
14	Summit Power Limited (SPL)	www.summitpower.org	Service Provider	Bangladeshi Independent Power Producer
15	International Islamic Relief Organization (IIRO)	www.islamicrelief.org.bd	Service Provider / Promotion	Active in biogas plant construction and financing
16	Bangladesh Animal Husbandry Association	www.sau.edu.com	Networking/ Livestock	Members could be potential clients in biogas market
17	Bangladesh Organic Products Manufacturers Association (BOPMA)	www.bopma.org	Organic Waste	Marketing organic fertilizer / compost
18	Chittagong Dairy Association (Ref. Dr. Ramiz)	www.facebook.com/Chittagong-Dairy-Farm-Association	Networking/ Livestock	Can set up biogas plants
19	Poultry Khamar Bichitra	www.poultrykhamarbichitra.com	Promotion	Publication to promote agricultural technology
20	Nestlé Bangladesh Ltd.	www.nestle.bd	Food processing & packaging	Food producer with capacity to generate biogas
21	Rangpur-Dinajpur Rural Service - RDRS Bangladesh	www.rdrsbangla.net	NGO / promotion	International NGO promoting agricultural livestock
22	Palli Karma-Sahayak Foundation (PKSF)	www.pksf-bd.org	Financing / promotion	Govt. organization; financing agro livestock projects
23	HELVETAS Swiss Intercooperation Bangladesh	https://bangladesh.helvetas.org	NGO / promotion	International NGO promoting agricultural livestock
24	Bangladesh Sugar & Food Industries Corporation BSFIC	http://www.bsfic.gov.bd/	Agro processing	Govt. own sugar mills having capacity to generate biogas
25	Chars Livelihoods Programme CLP	http://clp-bangladesh.org/	Promotion	International NGO promoting agro livestock

11. STRATEGIC PARTNERS FOR MARKET DEVELOPMENT

In general, biogas activities in Bangladesh have reached a certain maturity: the local partners and members of BBDF have the capacity to design, construct and commission medium size fixed dome biogas plants, and one service provider has already started to introduce with international support large-scale modern CSTR and other appropriate biogas technology. Other service providers are interested to promote internationally successful operated lagoon technologies.

It is further envisioned that the Memorandum of Understanding between BBDF and GERBIO, signed on December 6, 2015 in Dhaka, will contribute to strengthening the sustainable market development for successful performing agro-industrial biogas systems with a range of advanced anaerobic digestion technologies. GERBIO's support also includes support from the European Biogas Association (EBA). It also implies the support of Chinese medium and large scale technology, transferred under the guidance of the Centre for Sustainable Environmental Sanitation of the University of Science and Technology Beijing, and its representative in Bangladesh, Prof. Mang.

In Bangladesh, strategic partners for sustainable agro-industrial biogas market development are – besides SREDA, GIZ, KfW, and IDCOL, BCSIR, BUET, DoE, DLS, SAU, BAU, BARC, RDA, IFC, The Renewable Energy Centre of Dhaka University, the local banks various ministries preclude the support of these bodies, a broad range of stakeholders who could support these efforts within their specific sector. This group includes governmental bodies, local banks, universities and research institutes, as well as international donors.

BBDF has received delegations from African, European and Asian countries dedicated to the furtherance of the national and international biogas movement. The Grameen biogas story and IDCOL's novel financing pattern have earned recognitions of foreign organizations who are exchange their views with us by visiting us.

Private enterprises both plant owners and service providers are also in partnership or in membership with BBDF to render their support to biogas activities of BBDF. It's in the interest of Biogas and BBDF to expand the partnership base to include newer ideas and technologies in this developing field.

The biogas program for its success will depend on both local and foreign partners. The network today and can offer plants and technology form the smallest to the largest through strategic partners supporting the activities. The local partners of BBDF have the capacity to build the medium size plants. Larger plants can be built with the support of GERBIO's member companies though a contractual agreement.

Thus, BBDF could play the facilitating role for all sector players to understand the applicability of solutions to their requirements.

The following table shows a selection of 23 strategic national partners for market development. They are identified among rural development institutions, environmental organizations, international donors, and policy and regulations makers. The list is not exhaustive, and should be updated step-by-step during the implementation of the roadmap for market development.

	of Bankers			projects
2	Bangladesh Energy Regulatory Commission (BERC)	www.berc.org.bd	Regulatory	Tariff setting and project approval authority. They can intensify projects by Feed in grid Tariffs (FIT) setting.
3	Bangladesh Environmental Lawyers Association	www.belabangala.org	Networking	Environmental Lobbyists
4	Dhaka South City Corporation (DSCC)	www.dhakasouthcity.gov.bd	Organic Waste	Possibilities for biogas from municipal waste exists
5	Dhaka North City Corporation (DNCC)	www.dncc.gov.bd	Organic Waste	Possibilities for biogas from municipal waste exists
6	West Patiya Development Association	www.bangladesh-economy.org	Promotion	Situated in CTG Milk hub
7	Chittagong Hill Tracts Development Foundation/ UNDP	www.chtdf.org	Promotion	This is a regional development body with the charter to develop potential sources of energy in the three regional districts of CTG hill tracks
8	Bangladesh Water Development Board	www.bwdb.gov.bd	Promotion	Has interest in water quality protection from pollution by animal wastes
9	Summit Power Limited (SPL)	www.summitpower.org	Energy Service Provider	Bangladeshi Independent Power Producer
10	International Islamic Relief Organization (IIRO)	www.islamicrelief.org.bd	Service Provider / Promotion	Active in biogas plant construction and financing

	(BPDB)			RE projects
13	Department of Agricultural Extension	www.dae.gov.bd	Promotion	Can promote agro waste based biogas plants
14	Bangladesh Agricultural Research Institute (BARI)	www.bari.gov.bd	Regulatory	Research institute on agro waste
15	Chittagong Dairy Association (Ref. Dr. Ramiz)	www.facebook.com/Chittagong-Dairy-Farm-Association	Networking/ Livestock	Can set up biogas plants
16	Ministry of Youth and Sports	http://www.moysports.gov.bd/	Policy	They already have an ongoing biogas training and financing program
17	Dept. of Environment (DoE)	www.doe.gov.bd	Policy & Regulations	All permissions regarding Environmental Impact Assessment (EIA); key institution to control pollution and ensure setting up of biogas plants
18	Rangpur-Dinajpur Rural Service - RDRS Bangladesh	www.rdrsbangla.net	NGO / promotion	International NGO promoting agricultural livestock
19	Palli Karma-Sahayak Foundation (PKSF)	www.pksf-bd.org	Financing / promotion	Govt. organization; financing agro livestock projects
20	HELVETAS Swiss Intercooperation Bangladesh	https://bangladesh.helvetas.org	NGO / promotion	International NGO promoting agricultural livestock
21	Renewable Energy Research & Development (RERD) in the Bangladesh Power Development Board (BPDB)	http://www.bpdb.gov.bd/	Policy	Sustainable renewable energy of PDB
22	US Aid	www.usaid.gov/bangladesh	International donor / promotion	US govt. agency promoting agro livestock projects in Bangladesh

12. Policies related to agro-industrial biogas plants, value chain and market development

Policies, which impact the development and the sustainable consolidation of the agro-industrial biogas market in Bangladesh, are numerous. The study team identified the following policy categories:

- Agricultural policies & regulations, esp. on fertilizer
- Construction & technology regulations (National Natural Gas Code)
- Social policies & regulations (social safeguards, workers' health regulations)
- Environmental policies & regulations
- Energy policies & regulations (including Feed-in-grid tariffs)
- Import policies & regulations

However, even intensive research to date has not led to the discovery of any policy which is supportive to sustainable market development for medium and large scale biogas systems.

The study team concluded that national decision makers relate the term 'biogas technology' to household sized biogas systems, and have not yet been informed about the huge potential, anaerobic technology offers to the energy sector, environmental protection, climate change mitigation, food security and the national economy through job creation, renewable energy and fuel production and waste re-valuation.

12.1 Agricultural and Fertilizer Policies and Regulations

In April 1999, the Ministry of Agriculture published the National Agriculture Policy. Paragraph 5 is dedicated to the use of fertilizers. It highlights that chemical fertilizers are a main input in increased crop production, but at the same time their unbalanced use causes a decrease in soil fertility.

Therefore, the policy recommended to popularize granular urea, organic manure, bio-fertilizer and compost.

The National Fertilizer Standardization Committee under the Ministry of Agriculture, decided on 17 June 2015, about the formulation of a policy on the usage of liquid fertilizer, which was – and still is banned from import. However, to formulate policy on the production, sale and distribution of quality liquid fertilizer in the country, it was decided in March 2014 to form a 6-member committee with representatives of DAE, BINA, BARK and SRDI making the joint-secretary (procurement) of this ministry as the chairman. The committee took the opinions and suggestions of the Technical Sub-Committee on Fertilizer, which perceives the approval of the production of liquid fertilizer inside the country as an act against the General Agreement on Tariffs and Trade (GATT) treaty and a breach of open market economy while the import of liquid fertilizer stays prohibited.

Upon detailed discussion, the previous prohibition on the import of liquid fertilizer was stayed and it was decided to prohibit/stop the production of liquid fertilizer inside the country. This decision poses a huge barrier to the feasibility of agro-industrial biogas systems. The study team does not find any logic to prohibit the production of liquid fertilizer based on the GATT treaty. There are other commodities which are banned for import but produced locally such as eggs.

Already in April 2008, the Ministry of Agriculture (MA) published a Circular (No. MA/Pro-2/Fertilizer-1/2008/156) related to the Fertilizer (Management) Act, 2006, the ruling on Organic Fertilizer, listing the following characteristics of the product:

Parameter	Content
Physical	
Colour	: Dark gray to black
Physical condition	: Non-granular form
Odour	: Absence of foul odour
Moisture	: Maximum 10-20%
Chemical	
pH	: 6.0- 8.5
Organic Carbon	: 10-25%
Total Nitrogen (N)	0.5-4.0%
CN	Maximum 20
Phosphorus (P)	0.5-3.0%
Potassium (K)	0.5-3.0%
Sulphur (S)	0.1-0.5%
Zinc (Zn)	Maximum 0.1%
Copper (Cu)	Maximum 0.05%
Arsenic (As)	Maximum 20 ppm
Chromium (Cr)	Maximum 50 ppm
Cadmium (Cd)	Maximum 5 ppm
Lead (Pb)	Maximum 30 ppm
Mercury (Hg)	Maximum 0.1 ppm
Nickel (Ni)	Maximum 30 ppm
Inert Material	Maximum 1%

FIGURE 18: CHARACTERISTICS OF ORGANIC FERTILIZER

All organic fertilizers should be produced from organic materials and no inorganic materials (such as plastic material) or toxics and waste, esp. hospital waste can be used. The names/sources of the organic materials with which the organic fertilizer has been produced should be clearly mentioned in the application for the determination of the standard of organic fertilizer.

To determine the quality of organic fertilizer, the production process of organic fertilizer should be physically inspected by 2 members of BARI/ BINA/ SRDI nominated by the convener of the subcommittee including the representatives of the Agriculture Extension Department as inspector on behalf of the under The Technical Sub-Committee on Fertilizer under the Fertilizer (Management) Act, 2006 and upon collecting specimen randomly from the production site should be sent to at least 3 laboratories for test. Tyurin's Method (1931/1936) as unified method should be used to determine the quantity of organic carbon in the laboratories of 5 institutes (BARI / BINA / SRDI / BSTI / Dhaka University) referred by the government.

Overall information on the production process, such as aerobic or anaerobic or semi aerobic technology should be mentioned in the application for the registration of organic fertilizer.

Upon production of organic fertilizer after receiving the registration, the quality of organic fertilizer should be determined by referred laboratories after collecting random specimen from the open market through the representative of the Agriculture Extension Department. If proper quality is not maintained, then proper punitive action should be taken against as per the current law of the country. No organic fertilizer produced abroad can be imported/distributed/used in the country.

Analysing this regulation, the study team assumes that sundried bio-fertilizer can be sold as organic fertilizer provided the parameters mentioned above are maintained. To enhance marketing of sundried bio-slurry as fertilizer, testing from one Government accredited standard laboratory such as BSTI, BARI, BCSIR should be sufficient to register the product as organic fertilizer.

In the Draft National Manure Policy, December 2015, bio-slurry is mentioned, not in a prominent place, but at least mentioned.

12.2 CONSTRUCTION & TECHNOLOGY REGULATIONS

Bangladesh is following in gas grid design and safety the American National Standard Code for Gas Transmission and Piping Systems (ANSI-B 32.S); refer to Gas Safety Ordinance from 1991. For gas safety zoning (ATEX etc.) the Ordinance refers to the Rule 105 from the Petroleum Rules from 1937, still as acting law.

The Cantonments Act II from 1924, CHAPTER XIII "WATER-SUPPLY, DRAINAGE AND LIGHTING" article 230ff, is still applied for natural gas household distribution networks.

There is also a "Gas Act from 2010" and the "Draft Residential Policy Guideline 2013" from PETROBANGLA which should also guide the implementation of agro-industrial biogas systems.

The Environmental Impact Assessment of gas supply to households was evaluated in the ADB supported natural gas supply project in 2009, which could also be considered for any agro-industrial biogas project.

> *"65. At appraisal, the initial environment examination report concluded that the project did not produce any substantial adverse environmental impacts. Hence, a full environmental impact assessment was not required. The Environmental Authorities (EAs) advise that minor environmental issues were addressed properly during design and implementation of the project. The upgrading of the network has also helped to improve the safety of operations. The EAs currently apply international standards regarding their operations and maintenance. Although not analysed quantitatively, the use of gas in cooking has contributed to avoidance of domestic pollution and benefited women folk."*

Summary of Natural Gas Act 2010

Bangladesh Government introduced the Energy Regulatory Commission Act 2003, the Gas Distribution Act 2004 and the Gas Act 2010. Finally, GoB has prepared the “Gas Marketing Act 2013”, to reduce some rivalry issues between Energy Regulatory Commission Act 2003 and Gas Act 2010.

According to Act 2010, gas is defined as: natural gas or natural liquid gas (NLG), Liquidized Natural Gas (LNG), CNG, SNG, LPG, Coal bed methane (CBM), Underground coal transmitted into gas (UCG), and such a hydrocarbon or mixing hydrocarbon transmitted from normal temperature or gas pressure.

Chapter 1 provides a glossary related to gas.

Chapter 2 deals with business operation of gas supply from commission to users, construction of pipe line and its management

Chapter 3 deals with gas distribution and identifies the user classes

Chapter 4 deals with CNG, LPG, LNG and its uses

Chapter 5 deals with supply and storage of gas

Chapter 6 deals with criminal offence and its penalty

Chapter 7 deals with miscellaneous: annual report and annual financial statement

Gas policy guideline Act 2013 (applicable for residential inhabitant)

Chapter 1 presents the glossary

Chapter 2 explains the gas users and its characteristics

Chapter 3 describes gas connection, different types of fees or charges and security deposit including obligatory meter adoption, gas connection procedures, cost of connection fees, identify the diversity factor of users, per hour gas load, estimation of capacity of atmospheric Burner, security deposit fixation and its procedure of submission, commissioning

Chapter 4 clarifies the adoption of gas meter reading, bill preparation and sending to the customers

Chapter 5 deals with field inspection

Chapter 6 explains how to collect the access bill, compensation and pay back on Record Management System (RMS) products damage or stealing

Chapter 7 deals with connection discard and its payment

Chapter 8 deals with gas load reduction/increase/ restructures charge

Chapter 9 deals with miscellaneous: Riser/ RMS/ CMS transfer fee, fee of ownership change, load transfer, correction of meter reading, conductor inclusion, solution of rivalry, right establishment

The **Strategy for Primary Energy Sector describes in the 7th Five Year Plan 2016-2020** under chapter "Supply of Primary Energy", that in addition to LPG, Biogas can also be considered as the alternative of pipeline natural gas. Similarly to the LPG utilization policy, Biogas utilization policy may also define how Primary Energy, namely pipeline gas, LPG and Biogas can be best mixed.

12.3 HEALTH & SOCIAL POLICIES & REGULATIONS (LABOUR SAFETY)

The current state of law and regulation system to cover up the health impacts due to occupation hazards, are not specific, but rather general in nature. The amendments of Bangladesh Labour Act 2006, adopted on July 2013, were supposed to address the critical need of bolstering occupational safety and health. The conformity of the amended national legislation with international labour standards ratified by Bangladesh, was reviewed by ILO. The result: some of the international standards have been adopted, some still not.

In Bangladesh, it is estimated that 11.7 thousand workers suffer from fatal accidents and a further 24.5 thousand die from work related diseases across all sectors each year. (International Journal of Public Health and Safety, 2016). As agro-dominated country the entire sector contributes about 19.1% to the GDP, and employs approximately 50,28 % of the national labour force.

The International Labour Organization (ILO) Country Office in cooperation with the Ministry of Labour and Employment, Bangladesh Employers' Federation (BEF), National Coordination Committee for Workers Education (NCCWE), and further social partners and research institutions are working to foster a preventive safety and health culture.

To date, technical safety standards or worker's safety equipment could not be observed when visiting agro-industrial biogas systems across the country.

12.4 Environmental policies & regulations

The Environment Policy 1992 and Implementation Program, by the Ministry of Environment and Forest, contains little what could be related directly to agro-industrial biogas systems. However, in Paragraph 3.1 the policy document promotes to the increased usage of the environment friendly and less harmful fuels and alternative fuel. This phrase could be interpreted as encouragement for the use of biogas for cooking and electricity generation, as well as upgrading to Bio-Methane for vehicle fuel.

12.5 Energy policies & regulations (RE feed-in-grid)

The Renewable Energy (RE) Policy was edited by the Power Division of the Ministry of Power, Energy and Mineral Resources in December 2008. Under 1.3.4, biogas mainly from animal and municipal waste is mentioned as "one of the promising renewable energy resources for Bangladesh. The technology is described as household and village technology. According to this policy document, its potential for rural and peri-urban electrification is limited to "provide electricity during periods of power shortfalls".

The RE policy includes also in 5.2 the exemption from charging 15% VAT for all RE equipment and related raw materials to prompt the progress of RE in the power sector. Under 5.7 RE project investors (both public and private) are exempted from corporate income tax for 5 years, with opportunity to extend the time line. Chapter 6 of the RE policy is dedicated to regulations; 6.1 determines that the sale of RE electricity requires obtaining a power generation license from BERC, but only if the capacity of the RE project achieves 5 MW or more.

In December 2012, a law was formulated to establish SREDA (Sustainable and Renewable Energy Development Authority) with a purpose to ensure fuel security

(Act No. 48 of the Year 2012). This law defines “Renewable Energy” as referring to “fuel and energy generated from biomass (fuel wood, rice husk, bagasse, waste, etc.) bio-fuel, biogas, hydro-power, solar energy, wind power, hydrogen cell, geothermal, sea-tides and waves, and the fuel and energy received from any other source, which is proclaimed as renewable fuel by the government, through government gazette circular from time to time.” Justification for this law is given as the need to extend the use of renewable energy by gradually decreasing the dependency on fossil fuel to control global warming, decrease natural calamities and for fuel security. In addition, it is possible to prevent the waste of fuel and play role in decreasing the global warming through preserving fuel and its efficient usage; and to ensure fuel security.

As another example: Biomass and biogas-based power generation is not yet an “Eligible Entity” in the 2015 drafted Feed in Tariff for Wind & Solar Electricity Regulation from the Bangladesh Energy Regulatory Commission.

12.6 IMPORT POLICIES & REGULATIONS

The Ministry of Commerce published the IMPORT POLICY ORDER 2012-2015 with the following content:

Sl. No.	Chapter	Subject	Page No.
1.	Chapter One	Prelude	1
2.	Chapter Two	General Provisions for Import	5
3.	Chapter Three	Provisions Regarding Import fees	15
4.	Chapter Four	Miscellaneous Provisions	19
5.	Chapter Five	General Provisions for Industrial Imports	33
6.	Chapter Six	Provisions for Import by Commercial Importers	45
7.	Chapter Seven	Import by Public Sector Importers	59
8.	Chapter Eight	Import Trade Control (ITC) Committee	60
9.	Chapter Nine	Compulsory Membership of recognised Chamber of Commerce and Industry and Trade Association.	61

FIGURE 19: CONTENT OF IMPORT POLICY ORDER 2012 - 2015

This policy order is very general and does not provide for clear indications on the potential import of biogas technology components.

13. Selected conclusions & recommendations for agro-industrial biogas market development

13.1 Policies & regulations & Finance

Presently there are no policies and regulations for certifications neither of service providers, nor of components for, and end products of agro-industrial biogas systems. Headed by SREDA, a legalized committee should formulate policies and regulations for certification procedures and criteria in the sector.

Biogas is never "inexpensive", as all larger scale biogas investments have not reached their return of investment point, because they went out of service before their expected service life was accomplished, or they are yet too recently in operation to evaluate this expected success.

After the installation of an agro-industrial biogas system, the farm must look shiny and not dirty, as the system should allow for the implementation of high level safety and environmental sanitation standards. Guidelines and licenses should be enforced by SREDA to take care of environment and climate, as well as sustainable development.

It is recommended to develop a NAMA Support Project, with SREDA, as one important implementation partner.

Biogas pipelines must be installed according to the national gas pipeline standard, and all biogas appliances should comply with national natural gas safety regulations. BBDF and BCSIR may be entrusted with this task.

SREDA as promotor of Renewable Energies may introduce a system to award best biogas practices in the medium and large scale categories. GIZ, JICA, IDCOL and BBDF could join in the award committee.

13.2 Capacity development

A survey on the Bangladesh Farm Poultry and Livestock published in 2010, reveals that poultry farmers are usually not members of any associations.

- Among all farms only 13% reported to be members. But more than 77% hatchery farms were members, while only 9% of duck farms were members of any association.
- Only 36% of a commercial cattle or dairy farms reported to be members of any association: about 60% cow rearing farms are not members of any associations, while 92% buffalo farms are not members of any association.

Therefore, offering biogas capacity development through associations will first only reach a minority of farm owners, although these are the biggest ones in their respective sectors.

The same survey reveals that

- 63.5% of all operational cost in the poultry sector is incurred for purchasing chicks.
- Rent of land and office operation are the second major expenditures accounting for 12.9% of all operational cost.
- Only 3.7% are related to energy and water consumption. Of course, the cost and structure are found different for different type of farms. Division wise variation is also observed.

Therefore, capacity building programs need to be specifically designed to target different audiences such as

- key stakeholders for policy formulation and advanced financing instruments,
- service providers for improved performance,
- media for awareness and information campaigns,
- private sector and professional associations for responsible business developments.

This list is not exhaustive.

13.3 TECHNOLOGY DEVELOPMENT

Through the stakeholder interviews it became clear that according to donors' opinion anaerobic digestion or biogas technology is labelled as a "simple" technology.

However, our field visit results show that biogas technology is never "simple" neither on household level nor at agro industrial level; even the old-fashioned brick-concrete fixed dome digesters are obviously too complex for satisfying performance, because service providers, operators, users or owners are often not able to make them perform at the intended design optimum.

The consultants visited - also beyond the present assignment, more than 60 agro-industrial biogas plants in the country. They therefore recommend that technology service providers should be trained to design correctly a modern and efficient biogas system. They should be supported to achieve international level standards of industrial biogas technology designs for poultry and cattle farms, food processing industries, and slaughterhouses. BBDF with GERBIO and other international partners can support these efforts to meet technology requirements according to national standards and to achieve sustainability of the projects.

13.4 MARKET DEVELOPMENT MILESTONES (ROAD MAP)

Biogas is produced in various domains where organic substrates are available. The main fields and their principle substrates are:

- Agriculture - manure, slurry, production residues and energy crops
- Agro-industry – industrial waste water with high organic load (slaughterhouses and meat processing, dairy industry, paper industry, soft drink production, sugar mills and distilleries)
- Bio-waste – organic fraction of municipal waste, restaurant and hotel waste, kitchen waste, fishery waste.
- Wastewater treatment plants – sewage sludge, faecal sludge

The expansion of the agro-industrial biogas market requires a proactive approach from interested parties to move the sector to new levels of performance and productivity. Compared to other “biogas” countries (Vietnam and China) GoB’s government departments such as agriculture, fisheries, livestock are not really involved in the larger scale agro-industrial biogas sector.

Before any transformation, the raw biogas needs to be dried and cleaned from H_2S and other trace substances to get a good combustible gas. Then, the biogas can be transformed into different forms of energy; electricity, heat and biomethane are the most employed options. The five typical concepts for agro-industrial plants are:

1. Commercial farm digesters in remote areas: Captive power or Cogeneration with injection of electricity into the grid, utilisation of the heat for process heat and productive use. The use of all produced heat is often not possible.
2. Commercial farm digesters near villages: Transport of the biogas in a dedicated pipeline to a cogeneration unit situated in proximity to a district Cogeneration system. Electricity is injected into the mini-grid, and the heat is fully used for cooling storage centres or for milk cooling (dairy sector). Demand for cooking fuel can be solved by supplying biogas to the villagers through gas pipelines.
3. Commercial farm digesters near other biogas farms: Transport of the biogas in a pipeline to a centralised upgrading station and injection of the biomethane into the natural gas grid or for bottling stations as practiced by RDA.
4. Centralised commercial plants in areas with high feedstock availability: Collecting and sorting organic waste and harvest residues and re-distribution of the digestate as fertilizer. Cogeneration with injection of the electricity into the grid, heat supply to industrial processes.
5. Centralised commercial plants in areas with high feedstock availability and proximity to a gas grid: Collecting raw sorted waste, sludge, and harvest residues and re-distribution of the digestate as fertilizer. Biogas upgrading and injection of the biomethane into the natural gas grid or bottling.

It may be reminded, that based on European experiences, biogas technology – compared with other decentralized consumer near renewable energies, has the

- highest national economic value
- highest job creation potential
- highest business for small and medium enterprises
- highest security of energy supply & storage
- highest CO_2 savings in transportation fuels

The study team therefore proposes a road map with two parallel tracks towards a sustainable agro-industrial biogas market: **track 1** is reserved for service providers; **track 2** is dedicated to sector key actors and the public. If one track will be neglected, the other track by itself and its own efforts will not be able to achieve the goal of a sustainable agro-industrial large scale biogas plants. In other words:

1) without highly motivated, open minded, well trained and knowledge-able service providers, no modernization of the sector will be possible, and within a short period the reputation of anaerobic digestion technology would be damaged in Bangladesh;
2) without including a pro-active role of the public and the sector key actors, no policy change will happen, no awareness and demand for a ‘green economy’ will be created, and no supportive climate change mitigation projects through well performing agro-industrial biogas systems will be successfully implemented in the sector.

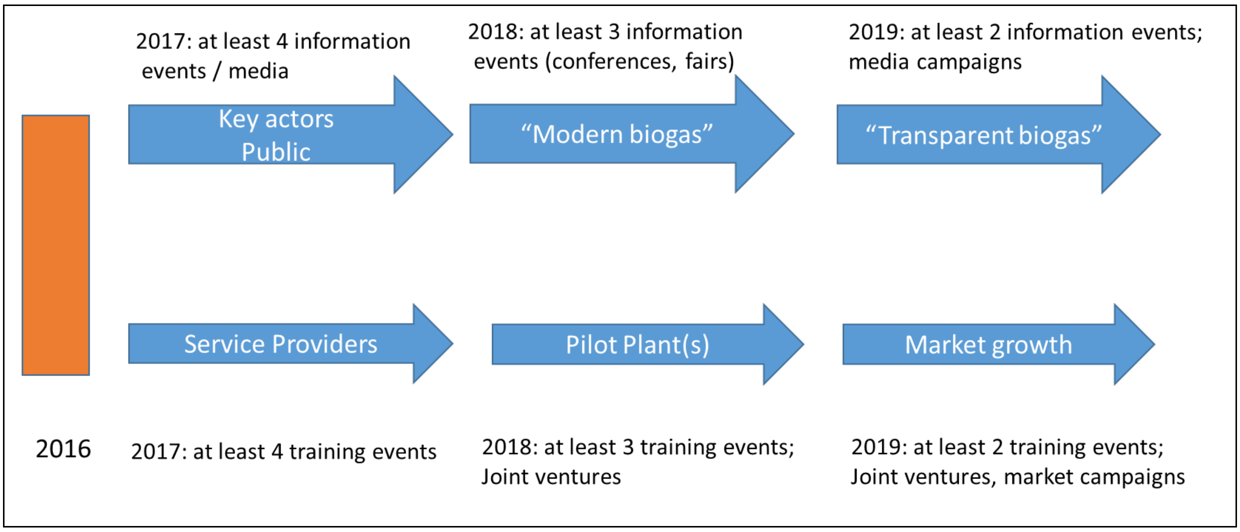

FIGURE 20: ROAD MAP TOWARDS A SUSTAINABLE AGRO-INDUSTRIAL BIOGAS MARKET

The essential, if not crucial components of building and maintaining this roadmap are briefly presented in the following sub-chapters. They include training, media campaigns, international joint ventures for pilot plant implementation, policy making and conferences, and exposure visits.

Track 1

13.4.1 TRAINING FOR SERVICE PROVIDERS

Four main sectors must be addressed for essential improvements of the framework conditions for biogas projects: authorities, banks, project developers, and technical service providers. Capacity building is the most important aspect for a better understanding of the biogas technology, its potential and benefits. It is the basis for the further establishment of clear, simple and adequate procedures.

To overcome staffing problems (missing state-of-the-art knowledge; quality issues) in the sector, short and long-term training programs are required, in which biogas technology explicitly for agro-industrial enterprises is demonstrated as modern and respectable technology. This includes lectures on anaerobic processes, planning and design in theory and practice, performance monitoring and business models – just to name a few.

Capacity building for authorities: general information about biogas, benefits, potential and examples of success stories, to distribute clearly the responsibilities among the authorities, provide a guideline "Permitting procedure for biogas projects", including all required permits, conditions and the necessary documents to receive them, costs, number of days/weeks to obtain the permits and the responsible body

- This should include specific training of financial service providers as well, from governmental sector and from private banks. Banks must be addressed for a better understanding of the biogas technology, its potential and the risks, with the objective of easier access to loans for projects. If possible under Bangladesh Bank Law, banks should relate to BBDF's knowledge to evaluate a biogas project's risk and potential for sustainability.

Project developers, too, must be informed to follow-up properly their biogas projects and to provide the necessary documents to authorities and banks. SREDA supported by BBDF may indicate the way how biogas project developers could be encouraged and guided.

13.4.2 Promoting Joint Ventures for Implementation of Pilot Biogas plants

These training sessions would be linked to the preparation of potential joint ventures between Bangladesh and international biogas enterprises, like GIZ has practiced in 2009 – 2014 in China. International companies will train and assist national service providers in planning and design of appropriate agro-industrial biogas systems, and the national partners will construct the state-of-art systems, supported where ever necessary by their international partners. The signed Memorandum of Understanding between GERBIO and BBDF can probably be one step towards the implementation of a successful agro-industrial biogas pilot project in Bangladesh.

13.4.3 Market Growth Activities

Specific activities which target and contribute to market growth include – but are not limited to:

- Green Financing for agro-industrial biogas systems provided by national banks and international donors, based on realistic business plans including the marketing of gas, power and slurry for revenue generation
- Establishing a strong supply chain for state-of-art material and equipment for the implementation and operation of agro-industrial biogas systems
- The identification and setting up of marketing channels for products from agro-industrial biogas systems
- The creation of a scientific foundation of marketing activities by comparing the reliable impacts of bio-slurry and chemical fertilizer on soil fertility, environment and climate in Bangladesh; webinars could be arranged by BBDF at national and Upazila levels
- Capacity building programs for local entrepreneurs who live in the neighbourhood of agro-industrial biogas systems and could take over relevant day-to-day operation and maintenance services including seminars, workshops, E-book and online newsletters
- Biogas sector professionals to open their capacities towards waste-to-energy systems, including their installation at food processing factories, municipal organic waste and wastewater treatment plants

- Standard setting for organic products to be marketed on national and international markets
- Promote Business Travels for Joint Ventures, and Marketing Campaigns combined with Training Events, regional and international conferences;
- Provide support to identify, document and publish “best practise” in the Bangladesh agro-industrial biogas sector.
- Develop a legislative framework for bio methane injection, distribution and use
- Develop guidance for digestate management and use
- Promote the organic waste recycling and source separation of household waste to use the organic fraction of the solid municipal waste for anaerobic digestion. City corporation /local bodies may frame laws to ensure source separation and management of solid municipal waste
- Promote local research capacity in the field of biogas and cooperation between scientists and biogas industry. As funds are available under HEQEP, universities and research bodies may undertake R&D in the local context
- Promote the growth of BBDF as national biogas association (Focal Point of Biogas Industry), to help farmers and investors, guiding them through successful medium and large scale biogas projects
- Provide a guideline: “Financing of biogas projects” including a list of national and international support instruments and banks interested to finance biogas projects

Track 2

13.4.4 MEDIA INFORMATION EVENTS TARGETING KEY ACTORS AND THE PUBLIC

Media coverage of sector relevant topics should be supported by GoB, highlighting the multiple benefits of the technology, and of producing and applying bio-slurry in agricultural lands. Media and information campaigns could be realized through a blended approach including media articles, movies, road shows, focal group discussions, national dialogues, academic workshops and whatever will be developed by a professional media agency.

Key stakeholders would enhance leadership development in the agro-industrial biogas sector through favourable policies in view of safe waste treatment, clean energy production, and organic based food security.

Main target for information campaigns and knowledge improvement must be the regional authorities, which are mainly responsible for permissions and commissioning of biogas plants. The goal must be to assist them defining a clear step by step procedure and to help them assigning responsibilities among the different stakeholders involved.

Consumers' awareness development program should address both governmental departments and non-governmental organisations as well as the general public to spread the message about environmental sound technologies for waste treatment.

Business Travels and Round Tables to support Joint Ventures, and Marketing Campaigns combined with information events for key actors, media and interested public.

13.4.5 ORGANIZING BIOGAS CONFERENCE WITH FAIR FOR MODERN BIOGAS SYSTEMS

Looking only at agro-industrial biogas systems, reduces the potential of the technology to one sector only. There are a lot of opportunities for anaerobic digestion systems to improve the environment and climate impacts from other industries, such as the garment sector, through efficient waste water treatment up to high water quality standards. Problems with natural gas and energy supply could be solved by strategic implementation of medium and large scale biogas systems with feed-in-grid technology.

In addition, modern biogas technology has been proven in countries like China, Sweden and Germany to be beneficial for national economic development and job creation. In conferences on anaerobic digestion system, a wide range of Governmental ministries could therefore be invited to participate, for example the Ministry of Environment, the Ministry of Law and Labour, and the Ministry of Finance, Ministry of health and power.

To create a sustainable market, biogas technology must be promoted as a future oriented technology in national and international forum and as a key green technology to ensure better public health; safe and organic food for all; environment and sanitation improvement for all; and greenhouse gas (GHG) emission reduction for minimizing global warming.

13.4.6 TRANSPARENCY OF BIOGAS TECHNOLOGIES WITH EXPOSURE VISITS FOR MEDIA AND PUBLIC

For increasing the market, customers must know the benefits of the technology, and they must have confidence that they invest their money into a long-term reliable product. To this end they need at least a comprehensive understanding of the technology and its potentials. As this understanding needs to be maintained throughout a longer period, a centre of excellence for the country specific promotion and to-date R&D on biogas should be established, best connected to a university – for example the Bangladesh Agricultural University (BAU), where young professionals are educated.

Provide opportunity for exposure visits, organised in that form so that biogas interested “people” living in one place can visit an operating large scale biogas system to observe and learn from these. Participants may be a short distance from one another, or in some cases, in different regions or even different countries. Consider the possibility of reciprocal visits or longer learning tours involving visits to various biogas locations.

14. Conclusions & Recommendations

No.	ToR	Conclusions & Recommendations
0	Methodologies; interview and assessment guidelines for biogas plant performance assessment; market study; interview outlines for data collection and analysis	Methodologies, interview and performance assessment guidelines are elaborated and could be made available for future sector review and monitoring of the sector development
1a	Desk study, meetings, visits to identify potential agro-industrial biogas clients / biogas relevant industries, as well as decision making key stakeholders for the biogas sector Stakeholder workshops to present (1) national and international agro-industrial biogas technology; (2) obtain general opinions from potential clients and strategic allies for agro-industrial biogas market	Potential stakeholders and public are not informed about biogas technology applications; Establish a unified data base of commercial / agro-industrial biogas plants; Recommended to implement periodically information events / fairs / advertising sessions on renewable energies and esp. on biogas technology for agro-businesses (benefits: waste valorisation; clean energy supply; job creation; fertilizer …) Revue the biogas plant design for poultry farms and introduce denitrification measures (technologies) for the remaining liquid effluent to recycle the water back for the dilution. Introduce updated biogas plant technologies (heated CSTRs), approach's (manure scrapping, dry stable cleaning, conveyer belt collection, instead of flushing droppings with huge amount of fresh water) and concepts (for effluent post-treatment) especially for biogas systems from poultry farming.
1b	Assessment of a feasible market for a commercial biogas subsector considering both the demand and supply Secondary literature review and key informant interviews representing the demand and supply side.	12 Key Informant interviews and 2 stakeholder workshops showed the usefulness of communication about biogas sector development: o Potentials o Demand side: 130,000 medium and large sized farms – poultry, cattle, fisheries; food processing industries; o Supply side: technical capacities for understanding and implementation of advanced technologies o Gaps o Demand side: enabling environment / policies / financial support o Supply side: technology update; joint ventures

<table>
<tr><th>No.</th><th>ToR</th><th>Conclusions & Recommendations</th></tr>
<tr><td></td><td>Discussion with SREDA and sector key stakeholders to clarify the term “commercial agro-industrial biogas”</td><td>National agreement on definition postponed, but required!
The consultants are recommending: “Commercial Biogas Plants or Biogas Plant Systems” with an expected daily biogas production of more than 50m^3, or 300kWh/d thermal production capacity, or about 100kWh/d electricity production capacity.</td></tr>
<tr><td rowspan="2">2a</td><td>Service providers’ perceptions of their readiness to offer services from the planning phase, system design to construction, operation, maintenance, and after-sale services: capacity needs assessment guideline</td><td rowspan="2">Service providers want to overcome the limitations experienced in the development of the agro-industrial biogas sector in Bangladesh, which they say is due to their limited technology knowledge: they are bound to design and construct only fixed dome digesters which are based on the household models, but not appropriate for medium and large scale biogas systems. Although they are mentioning the economic limitations for modern technology, they are interested in advanced technologies, in regular design and engineering training, and in joint ventures with international biogas companies from Europe or China.
Recommendations: support service providers as soon as possible with adequate training measures and joint ventures
Rehabilitate and improve existing poultry biogas plants no more in operation due to sediments by emptying and installing stirring systems.
Apply appropriately the existing national gas and building standards for agro-industrial biogas systems and piping. It was confirmed by the Bangladesh Energy Regulatory Commission (BERC) that biogas as a kind of natural gas is regulated under the same national design and construction standards as natural gas. Under GoB rules, any gas exploration, production, transmission and distribution activities require permission from different government departments or organisations, including: the Ministry of Energy and Mineral Resources; the Ministry of Law; BERC; Petro Bangla; the Board of Investment; and the Department of Environment.</td></tr>
<tr><td>Service providers’ (technology / finance) technical competence, maintenance and repair work capacity, and strategies for good customer relations and further business development.</td></tr>
</table>

No.	ToR	Conclusions & Recommendations
2b	Clients' perceptions of their needs, and the options available to those who plan to invest in large-scale commercial biogas plants in Bangladesh:	Lessons Learned from owners of existing agro-industrial biogas systems: they are not aware of the technology options; they receive financial support only within some programs supported by international donors; Recommendation: business plans for investment support; systematic and realistic documentation of economic feasibility for each plant to allow for overall performance analysis; standardized installation of measurement equipment

No.	ToR	Conclusions & Recommendations
2c	Secondary services, like bio-slurry management, production and marketing of organic fertiliser – currently provided or needed for future market development.	Conclusions from interviews with agro-industrial enterprises (poultry (broiler and layer)), dairy, cattle, fish, meat processing, distilleries, sugar), including both biogas plant owners and future potential clients, and site visits to 30 commercial biogas plants (medium and large scale) underline that primary and secondary services for and from biogas plants must be included in serious business plans. The following specific recommendations are relevant to slurry practices of agro-industrial based biogas production in Bangladesh: • Biogas producer may use the bio-slurry as soil-improver to his land or he/she should be enabled to sell this bio-slurry as organic fertilizer. But before trading the bio-slurry, it needs laboratory test and expert recommendations how apply to agricultural field according to the soil nature. It is verified by experiments, that bio-slurry has good nutritional value, like NPK convenient for agricultural production. But conventional farmers should not rely on the nutritional value of bio-slurry. • Bio-slurry is organic fertilizer, it should be recognized by Department of Agricultural Extension (DAE). DAE must take the responsibility the extended the bio-slurry application practices in Bangladesh. The procedure of organic fertilizer license issued should be smart and business convenient. • Ministry of Energy, DAE and IDCOL and other governmental financial agents may establish contractual agreements on biogas technology extension as well as enhance the bio-slurry practice. Agreement should be conducted with bio-slurry producers and organic fertilizer organizations. Best is to form a National Organic Fertilizer Association, shape and activity will be looked like the Chemical Fertilizer Association. • Encourage the agro-based entrepreneurs to build organic fertilizer companies that should be based on slurry. This company will have contractual agreement with bio-slurry producers and the company will collect the slurry from the field timely.

No.	ToR	Conclusions & Recommendations
2d	Status of policy, strategies and laws in Bangladesh to promote agro-commercial biogas technology; as well as the client-friendliness of laws and policies, regarding (rural) grid-connection policy to feed-in-grid electricity, captive power use, bio-methane as transport fuel, greenhouse gas emission reduction benefits, wastewater treatment co-benefits, soil improver and organic fertilizer	Conclusions: policies in place are neither fit to promote agro-commercial biogas technology nor to promote rural feed-in-grid-connections Recommendations: support through green electricity and circuit economy policy to promote the biogas sector growth
2e	Further stakeholder related conclusions & recommendations	Road map for market development considers the range of sector stakeholders and supports them according to their needs to overcome role-specific deficits Increase customer's knowledge on biogas technology by organizing sector outreach workshops and presenting best (international) practice examples and Bangladesh specific financing concepts.

No.	ToR	Conclusions & Recommendations
3	Conclusions for future market potential and market development	Recommendation: Conduct an in-depth analysis with SREDA and GIZ selected stakeholders, discussing recommendations for action plan for sector empowerment and the proposed road map for market development. Identified key barriers: 1. biogas-to power is not yet included in feed-in-grid tariffs (only solar, wind, hydro), neither for electricity nor for mixing bio-methane in natural gas grid; therefore, nowadays business plans could mainly be based on captive power generation and not on revenues from power sale; 2. no effective environmental protection promoting subsidies are provided to large-scale agro-industrial biogas systems, mostly loans at interests which result in additional burden to the system owner; 3. the plant technology and construction method level – based on the household digester models, is obviously not suitable for large-scale systems (blockages and clogging due to sediments in poultry droppings fed digesters; no measuring devices installed to proof service hours of generators and other equipment, and amount of biogas and kW produced 4. no tariffs are in place for electricity produced through bioenergy; 5. no incentives for RE use are established, neither for the consumers nor for the producers of clean energy.

In addition to the above-mentioned recommendations, the following key-recommendations were collected from the public expert audience in the SDREA workshop on December 18, 2016, in Dhaka:

1. Create actual value chain examples with biogas plant, add these as activity in the proposed road map.
2. Use the since 2015 established collaborative partnership with GERBIO and BBDF for training and research on modern biogas development issues.
3. Feedstock could become a value, i. e. rice husk and water hyacinths have rising prices which create serious problem of extending the betterment of biogas or other bioenergies. In this regards government should have a green electricity incentive policy.
4. Currently the major problem is with poultry dropping based slurry digestate management in Bangladesh. It needs more improved technology for a better management of poultry drooping based bio-slurry.
5. Install a mixing device inside a big dome digester, such examples should be developed in the road map as activity.
6. How government is managing to issue organic fertilizer certificates to the poultry dropping based slurry, which has a heavy lime content of about 4 to 14% lime stone? This amount of limestone should not be certified as a complete organic fertilizer.
7. Promote systematic collaboration with donor agencies which are currently working on bioenergies issues in Bangladesh, because mostly donor agencies are working in their separate and uncoordinated way.
8. Green banking in Bangladesh Bank are ready to sanction the loan for renewable energy components especially in the biogas cases, but they don’t have get adequate responses from the entrepreneurs, this may be analysed in depth in the road map.
9. Analyse and show sector wise where biogas is playing a model role in the country, and what are the barriers of extending these sector in the future.

Sustainable and Renewable Energy Development Authority (SREDA)
Power Division
IEB Building (9 & 10th floor), Ramna, Dhaka
www.sreda.gov.bd

Ref. No: 27.02.0000.000.29.001.14-1667 Date: 08/12/2016

Notice

A stakeholder validation workshop on the study report entitled **"Situation Analysis and Future Perspective of Agro-Industrial Biogas Plants in Bangladesh"** will be held on 18 December 2016 from 3:30 pm to 5:00 pm at SREDA Multipurpose Conference Hall, IEB Building (9th Floor), Ramna, Dhaka. The workshop will be chaired by the Chairman (Additional Secretary) of SREDA Mr. Md. Anwarul Islam Sikder ndc.

Your spontaneous participation is highly solicited.

08/12/16
(Kamrul Ahmed)
Deputy Director (Wind & Others)
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Copy for distribution (Not according to seniority)

1. Chairman, Bangladesh Energy Regulatory Commission (BERC) (With request to send appropriate representative)
2. Mr. Siddique Zobair, Member (Energy Efficiency & Conservation), SREDA
3. Mr. K. M. Abdus Salam, Member (Renewable Energy), SREDA
4. Mr. Mohammad. Alauddin, Joint Secretary, Renewable Energy, Power Division
5. Mr. Md. Faruque Ahmed, Chairman, Bangladesh Council of Scientific and Industrial Research (BCSIR)
6. Dr. Abul Kalam Azad, Chairman, Bangladesh Agriculture Research Council (BARC)
7. Mr. Md. Raisul Alam Mondal, Director General, Department of Environment (DoE)
8. Mr. Ajay Kumar Roy, Director General, Department of Livestock Services (DLS)
9. Mr. Md. Hamidur Rahman, Director General, Department of Agricultural Extension (DAE)
10. Ms. Salima Jahan, Member, Policy and Research, SREDA
11. Mr. Sheikh Reaz Ahmed, Director (Renewable Energy), SREDA
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15. Dr. A.B.M. Sharif Uddin, Chief Executive Officer, Rajshahi City Corporation (RCC)
16. Mr. K. M. Rahatul Islam, Chief Executive Officer, Gazipur City Corporation (GCC)
17. Mr. Md. Nazmul Haque, Director, Directorate of Renewable Energy and Research & Development, PDB
18. Mr. S M Zafar Sadeque, Director, Renewable Energy, REB
19. Mr. Manoj Kumar Biswas, General Manager, Sustainable Finance Department, Bangladesh Bank
20. Prof Shah Md. Ahsan Habib, Director (Training), Bangladesh Institute of Bank Management
21. Prof. Dr. Md. Zahurul Haq, Professor, CES, BUET
22. Prof. Dr. Saiful Huque, Professor & Director, Institute of Energy, Dhaka University
23. Dr. Md. Monjurul Alam, Professor, Green Energy Knowledge Hub, Bangladesh Agricultural University
24. Dr. Nazrul Islam Khan, Project Director, Community Biogas Project, RDA, Bogra
25. Mr. Partha Pradip Sarkar, Project Manager, SRE,LGED
26. Country Director, UNDP (With request to send appropriate representative)
27. Country Director, World bank (With request to send appropriate representative)

28. Country Director, ADB (With request to send appropriate representative)
29. Mr. Formanul Islam, CEO, Bangladesh Infrastructure Finance Fund Limited
30. Ms. Hasin Jahan, Country Director, Practical Action
31. Mr. Muhammad TaifUl Islam, Clean Energy - Project Manager, IFC
32. Mr. Al Mudabbir Bin Anam, Programme Coordinator, SED Programme, GIZ
33. Mr. Jan Soehlemann Hendrik, ENDEV Country Coordinator, GIZ
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35. Mr. Rajeev Munankami, Senior Advisor & Team Leader, SNV
36. Mr. A. H. Md. Maqsood Sinha, Executive Director, Waste Concern
37. Ms. Farzana Rahman, SVP (Investment), Renewable Energy, IDCOL
38. Mr. Md. Wahidur Rahman, Unit Head (Technical), Renewable Energy, IDCOL
39. Mr. T. I. M. Rawshan Zadeed, Executive Vice President, IFIC Bank
40. Dr. Engr. Khursheed-Ul-Islam, Energy Expert
41. Prof. Dr. Nurul Islam, Energy Expert
42. Mr. M. A. Gofran, Chairman, BBDF
43. Mr. Ekhlasul Haque, Secretary, BBDF
44. President, Bangladesh Poultry Industries Association
45. Managing Director, Phenix Poultry Ltd
46. Managing Director, Paragon poultry farm
47. Managing Director, Kazi Poultry Farm
48. Mr. Rafiqul Islam, Project Manager, ACI-RDA Joint Project, ACI
49. Mr. Md. Kamal Hossaine, AGM, Navana Renewable Energy
50. Mr. Md. Rafiqul Islam Sohel, Managing Director, SEED Bangla Foundation
51. CEO, Grameen Shakti
52. Dr. Mahbub, Managing Director, Winsource
53. Mr. Niloy Das, CEO, Surge Engineering
54. Mr. Md. Mahmudul Hassan Emon, CEO, ACT Energy & Power
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61. Mr. Md. Rashedul Alam, Assistant Director (Solar), SREDA
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63. Mr. Toufiq Rahman, Assistant Director (Standard and Labeling) & PS to Chairman, SREDA

Distribution: For information

1. PS to Secretary, Power Division, Dhaka
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Agro–industrial Biogas Plants

Sustainable and Renewable Energy Development Authorities
Dhaka, 18 December 2016

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Situation analysis of the agro-industrial biogas subsector in Bangladesh

Joint study: **BANGLADESH BIOGAS DEVELOPMENT FOUNDATION & GERMAN SOCIETY FOR SUSTAINABLE BIOGAS AND BIOENERGY UTILISATION**

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Md. Naimul HAQUE, Shahed Israil KHAN, Elisabeth HUBA,
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Bangladesh, December 2015 to July 2016

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Scope of todays session ...

The present study-project was undertaken **to gather sufficient information from a large variety of stakeholders to conclude whether there is a feasible market for commercial agro-industrial biogas systems under energy, environmental and fertilizer aspects**, keeping in mind also socio-economic development and animal welfare issues.

The here presented draft final study report therefore **provides an outline to induce a future sector review** for the commercial biogas subsector development.

The audience is warmly **welcomed to provide additional recommendations** to this draft study.

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Agenda

1. **Pre-conditions for a feasible market for a commercial biogas subsector**
2. **Readiness of service providers, service facilities, the service recipient and the policy environment to respond for commercial biogas sector development**
3. **Provide recommendations and insights as a way forward**
4. **Additional recommendations from the panel and the audience**

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Definitions applied in the study

Commercial biogas system

- Commercially driven and productive use of biogas to provide energy to sustainably serve the demand for income generation activities.
- Biogas system is used for:
  - producing electricity,
  - mechanical power,
  - transport fuel (bio-methane),
  - heat,
  - fertilizer,
  - soil improver.
- Bigger than household biogas plants.

Agro-industrial biogas system

"**Commercial Biogas Plants or Biogas Plant Systems**" with:

- expected daily biogas production 50+ m^3, or
- 300 kWh/d thermal production capacity, or
- 100 kWh/d electricity production capacity

Expected biogas production of 50+ m^3/d

Assumption: 1m³ biogas contains 6kWh/m³ thermal energy, and produces 2kWh/m³ electricity.

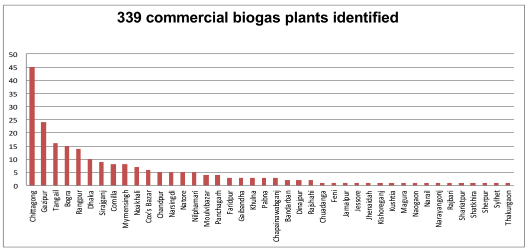
Depending of the efficiency performance (defined in m^3 biogas per day/m^3 fermenter volume), the required construction volume (liquid part) would range from:

- 50 m^3 (based on for modern agro-industrial usual: $1m^3/m^3$),
- 250 m^3 (based on psychrophilic conditions: 0.2 m^3/m^3),
- 100-125 m^3 (based on expected performance: 0.4-0.5m^3/m^3) (as usually expected in Bangladesh)

Survey approach

1. Collecting lists of biogas plants built (339)
   - Sources: Service providers, loan providers, technical assistance providers, development cooperation partners, resarch institutions, BBDF…
2. Screening, classification biogas systems (228)
   - Sources: Reports, definitions, feasibility studies, BBDF ...
3. Contacting owners and operators (102)
   - Sources: Documentation and information provided by owners, loan and service providers

Agro-Commercial Biogas Plants per District (03/2016)



Screening process with all identified biogas plants

228 Biogas plant systems from 6m³ to 2700m³ expected daily biogas volume (March 2016)

Circulating lists counted each biogas digester as an individual project, although on some farms and locations up to 7 biogas digesters were constructed and the biogas they are producing is used for the same purpose, either in one GENSET, in a joint group of GENSETs, or in the same gas mini grid systems for household biogas cooking stoves.

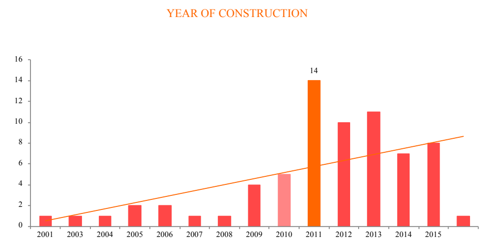
- **113 - 130 identified as agro-industrial biogas plant (AIBP) systems (50+ m³)**
- 102 owner or operators answered to first-level phone survey (CONFIDENCE LEVEL: 95% CONFIDENCE INTERVAL: 7)
- 70 resp. 34 responded to the second & third level phone survey (same confidence level as above)
- 36 systems were visited from December 2015 to June 2016

Energy output and social impact

Estimated **daily** biogas potential, reported substrate use (AIBP): 10,845

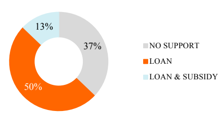
80%	Are in operation, 259 (AIBP) - 393 (all) operational working places were created
73%	AIBP producing electricity: 2.29 $MW_{inst.\ cap}$ Only 30-60% of the installed capacity could be used (limits)
54%	AIBP (all 61%) supply biogas in mini grid, 1350 families receiving daily cooking gas
4%	AIPB upgrading biogas to bio-methane 67% are not aware about this advanced option

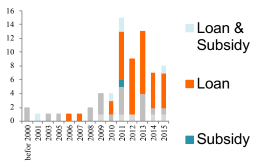
Agro-Industrial-Biogas systems in Bangladesh increased from 2009 onwards, one year after the "Renewable Energy Policy of Bangladesh" was approved



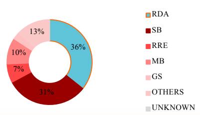
FINANCIAL SUPPORT RELATED TO THE YEAR OF CONSTRUCTION

RECIEVE FINANCIAL SUPPORT

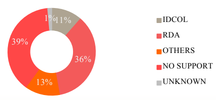




MARKET SHARE FOR DESIGN AND CONSTRUCTION OF AIBP



MARKET SHARE FINANCIAL SERVICES FOR AIBP



Agricultural and environmental impact

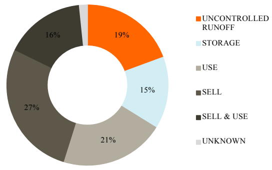
56% (AIBP) (all 65%) of the operators reported using or recognizing bio-slurry as fertilizer

27% for commercial use: selling it,
16% for both sales and own use;
13% all in own farm.

15% of operators are storing the slurry in open lagoons, but without having any further use in mind (drying by evaporation)

19% are discharging bio-slurry - at least partially uncontrolled - into public surface water bodies.

REPORTED SLUDGE MANAGEMENT



Criteria for Efficiency

Input:

investment cost; energy potential of substrate; working hours per day; fresh water use for substrate dilution

Output:

biogas yield per m^3 construction volume and per substrate unit; energy output (kWh electricity & m^3 cooking gas/d); bio-slurry amount and use

Identified minimum benchmarks

- **Produces min. 0.6m^3 biogas from each m^3 of digester volume** (average 0.5m^3/m^3 among non-benchmark)
- **Generator full capacity use is higher than 11%** (average 7.3%, including the mini grids)
- **Produce at least 0,22kWh_{el}/m^3 biogas** (incl. mini grid) (average 0.15kWh/m^3, including mini grids)
- **Produce 1m^3 biogas with less than 29 l fresh water** (general average is 36 litres/m^3 biogas)

9 systems identified as actual Benchmarks

PROJECT NAME	LOCATION	SIZE	FINANCIAL SERVICE PROVIDER	TECHNICAL SERVICE PROVIDER	FEEDSTOCK MATERIALS	ELECTRICITY PRODUCTION	GAS SUPPLY TO MINI GRID
KACHIBARIA BIOGAS PROCOLO	KHULNA, NARAIL, LOHAGORA, KACHIBARI	60	RDA	RDA	**COW**	NO	**YES**
MOJID FARM BIOGAS PROCOLO	RAJSHAHI, BOGRA, KAHALU, BAROMILE	60	RDA	RDA	**COW**	NO	**YES**
BIOGAS UPOPROCOLPO	DHAKA, KHILGAON, NASIRABAD	60	RDA	RDA	**COW**	**YES**	**YES**
KATAGORIA KRISHAK SOMBAI SOMITT BIOGAS	RAJSHAJI, BOGRA, SHAJAHAN, KATABARIA	60	RDA	RDA	**COW**	NO	**YES**
PARAGON GROUP LTD	DHAKA, GAZIPUR, SHREEPUR, MAUNA	600	BRAC BANK	C&F/HEEE	**POULTRY**	**YES**	NO
NRM BIOGAS (RDA)	RAJSHAHI, NAOGAON, NIAMATPUR, RUMKURHA	60	RDA	RDA	**COW**	NO	**YES**
AHAD DAIRY FARM	CHITTAGONG, ROWGAN, GOHIRA	80	Own	MASUM BIOGAS	**COW**	NO	**YES**
CHANDKARIM COMMINITY BIOGAS PLANT	RANGPUR, GAIBANDHA, SHADULLAPUR, CHANKARIN	60	RDA	RDA	**COW**	**YES**	**YES**
MOUSUMI MULTIPOURPOSE KHAMAR	CHITTAGONG, BOALKHALI, BOALKHALI BAZAR	140	OWN	MASUM BIOGAS	**POULTRY & COW**	NO	NO

Conclusions

1. **Medium scale biogas plants (50-99m^3/d capacity) built by Bangladesh biogas technology providers are operating best with cow manure as feedstock.**
2. **Mini biogas grids increasing efficiency of the overall system.**
3. **To treat poultry droppings, large-scale (500+m^3/d capacity) heated and insulated biogas plants with mixing devices (CSTR) and pumps are needed, which could currently not be offered by Bangladesh's technical service providers alone.**
4. **Co-digestion from poultry droppings pre-mixed with cow manure is manageable within the Bangladesh known technology approaches.**

Biogas Potential with dairy, cattle and buffalo farms

		Per farm (m^3/d)	average farm size (heads)	Total (m^3/d)
No. of dairy farms (total)	58,081.00			
No. of dairy farms with more than 50 heads of cattle	2,910.00	67.20	168	195,552
No. of cattle farms with more than 30 to 50 heads of cattle	5,148.00	19.60	49	100,901
No. of cattle farms with 11 to 29 heads of cattle	5,119.00	11.60	29	59,380
No. of cattle farms with 3 to 10 heads of cattle	44,904.00	3.60	9	161,654
No. of Buffalo farms (total)	1,924.00	-		
No. of farms with more than 30 buffalos	612.00	32.40	81	19,829
No. of farms with 11 to 29 buffalos	614.00	11.60	29	7,122
No. of farms with 3 to 10 buffalos	698.00	3.60	9	2,513
Potential based on total No. of cattle and buffalos (BBS, 2010)	60,005.00			546,852

Biogas Potential with poultry farms

		Per farm (m^3/d)	average farm size (heads)	Total (m^3/d)
Total no. of poultry farms	72,644.00			1,261,398
No. of broilers farms	53,855.00		34,873,000	
No. of layer farms	18,562.00		30,314,240	
No. of hatcheries (BBS, 2010)	227.00		3,867,000	
Farms with 1,000,000 birds and more	2.00	10,500.00	1,500,000	21,000
Farms with 400,000 – 999,999 birds	17.00	6,999.99	999,999	119,000
Farms with 50,000 – 399,999 birds	213.00	2,799.99	399,999	596,399
Farms with 20,000 - 50,000 birds	1,500.00	350.00	50,000	525,000
Farms with 10,000 - 19,999 birds	1,200.00	139.99	19,999	167,992
Farms with 5,000 - 9,999 birds	8,000.00	69.99	9,999	559,944
Farms with 1,000 - 4,999 birds	12,000.00	34.99	4,999	419,916
Farms with 500 - 999 birds	45,000.00	6.99	999	314,685

According to the Bangladesh Bureau of Statistics (BBS, 2010), there are over 70,000 commercial poultry farms in Bangladesh with about 1,700 farms having more than 10,000 birds.

Other identified agro waste for commercial biogas

1. Pressed mud and wastewater from sugar mill 5,000 MWh_{el}/y
2. Spent wash from distilleries 15,200 MWh_{el}/y
3. Waste from food processing industries (only from mango pulp 4 million m^3 biogas/y)
4. Waste from meat processing industries
5. Corn Stover
6. Potato plants and other agriculture starch waste
7. Water hyacinths
8. Maize plant residues
9. Pulp and paper industries 35-50$MW_{installed\ capacity}$

Summary of findings

1. **No unified data base neither technical standard on agro-industrial biogas plants exist in Bangladesh.**
2. **Technical and financial service providers have limited information about recent technological developments in the international biogas industry for medium and large scale biogas plants.**
3. **Only two biogas plants found are equipped with digester mixing device and are designed as thermal insulated CSTR.**
4. **There is a market potential for larger scale agro industrial biogas systems if properly designed, built and operated.**

Readiness of service providers, service facilities, service recipient and the policy environment to respond commercial biogas sector development.

Survey approach

1. Identifying agro-biogas stakeholders

- Sources: 20 professional and trade associations, 5 NGOs, 23 strategic partners for market development, 4 research institutions, BBDF …

2. Categorizing stakeholders

- Key informants (12), t&f service providers (14), clients (25), biogas plant owners or operators (30)

3. Interview stakeholders (76), Cap. assessments

- Two stakeholder meetings with 17 participants, specific interview guideline questionnaires, face-to-face meetings, phone interview, email exchange

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12 Key actors interviewed

1. Bangladesh Infrastructure Finance Fund Ltd. - BIFFL
2. Bangladesh Energy Regulatory Commission - BERC
3. Bangladesh Environmental Research Foundation - BERF
4. Infrastructure Development Company Limited - IDCOL
5. Bangladesh Agricultural Research Council - BARC
6. Bangladesh Agricultural Research Institute - BARI
7. Directorate of Agricultural Extension – DAE
8. Department of Environment - DoE
9. Directorate of Livestock - DLS
10. Mutual Trust Bank Ltd. & Association of Bangladesh Bankers
11. Sher-e-Bangla Agricultural University - SAU
12. Trust Bank Limited - TBL

Implemented by

Policies verified

1. Agricultural policies & regulations, esp. on fertilizer
2. Construction & technology regulations (National Natural Gas Code)
3. Social policies & regulations (social safeguards, workers' health regulations)
4. Environmental policies & regulations
5. Energy policies & regulations (including Feed-in-grid tariffs)
6. Import policies & regulations

Implemented by

BARRIERS TO MARKET DEVELOPMENT (1/4)

1. Biogas-to-power / bio-methane is not yet included in feed-in-grid tariffs, neither for electricity nor for natural gas grid;
2. Business plans are only based on captive power generation, economic targets for bio-slurry marketing usually not reached;
3. No effective (output oriented) subsidies are provided to large-scale agro-industrial biogas systems;
4. Technology level is obviously not suitable for large-scale systems, especially in poultry farms;
5. No measuring devices installed to compare service hours of generators and other equipment, with the amount of biogas and kW_{el} produced;
6. No incentives for RE use are established, neither for the consumers nor for the producers of clean energy.

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BARRIERS TO MARKET DEVELOPMENT (2/4)

7. Incentives for waste treatment in agro-industries - including farms, slaughterhouses, food & beverage producers, sugar industry, are required but not (yet) practiced.
8. Waste treatment is a major headache for agro-industries as it can contaminate the inner and outer factory environment.

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BARRIERS TO MARKET DEVELOPMENT (3/4)

11. Business plans for agro-industrial biogas plants should always put clear emphasis on the slurry management.
12. Slurry from poultry droppings is said to have toxic effects and demands to be treated properly before disposal.
13. Licenses, permissions, laws and regulations related to the agro-industrial biogas market do not yet really exist.
14. Organic fertilizer processing and marketing business is not yet well established in Bangladesh due to unclear legal framework, although more than 30 small and medium bio-fertilizer companies are operating.

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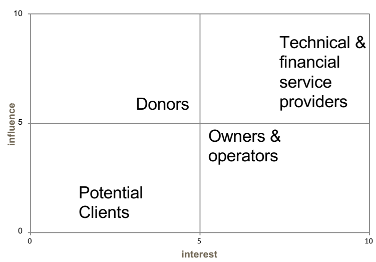
BARRIERS TO MARKET DEVELOPMENT (4/4)

15. There is a pressing lack of experienced trainers for design, engineering, construction, operation and management of large size agro-industrial biogas plants.
16. Only few of Bangladesh's biogas equipment providers deal with the required large-scale equipment for large size agro-industrial biogas plants.

Stakeholder analysis of given situation

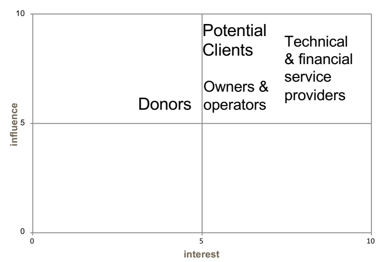


Findings

- Agro-Industrial Biogas Technology and its potential is mostly unknown among Key Actors responsible for opinion and policy making.
- Those who know the sector complain that neither service providers nor biogas system project developers (owners) have bankable business plans for biogas investments.
- Technology must be reliable – and currently it is not!
- Installation work must be professional – currently it is not!
- Financial services are limited to programs sponsored by international donors, these are offered in competition with different grant and technical assistance components.
- Slurry from cow manure is used widely as fertilizer and also to feed fishes; hence improve significantly rural income.
- Only 4% of the agro-industrial biogas installation is designed are engineered from foreign technical service providers, 96% is done by Bangladesh biogas experts.

Provide recommendations and insights as a way forward.

Target: stakeholder analysis for needed situation



Potential and gaps

1. Potential commercial demand side: 117,000 medium and 13,000 large sized farms – poultry, cattle, fisheries; food processing industries;
2. Potential supply side: technical capacities for understanding and implementation of advanced technologies available
3. Gaps on demand side: enabling environment / policies / financial support
4. Gaps on supply side: technology updates unknown; few technology joint ventures / cooperation's

How to boost the market

- Feed-in-grid regulations (gas & power)
- Upgrading to bio-methane & bottling biogas/ bio-methane
- Updated technology
- Training of service providers
- Certification for approved service providers
- Providing support for digestate processing

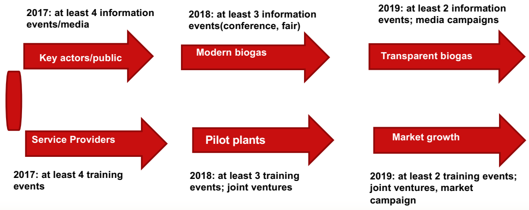
Five typical concepts for agro-industrial plants

1. Commercial farm digesters in remote areas
2. Commercial farm digesters near villages
3. Commercial farm digesters near other biogas farms
4. Centralised commercial plants in areas with high feedstock availability
5. Centralised commercial plants in areas with high feedstock availability and proximity to a natural gas grid

Proposed road map

Two parallel tracks towards a sustainable agro-industrial biogas market:

1. **Sector key actors**
2. **Service providers**



Recommendations (1/3)

1. Potential stakeholders and public should be informed about various biogas technology applications;
   - Establish a unified data base of commercial / agro-industrial biogas plants.
   - Recommended to implement periodically information events / fairs / advertising sessions esp. on biogas technology for agro-businesses.
   - Increase customer's knowledge on biogas technology by organizing sector outreach workshops and presenting best (international) practice examples and Bangladesh specific financing concepts.
   - Information need to be shared with private sector (waste producers);

Recommendations (2/3)

2. Business plans for investment support; systematic and realistic documentation of economic feasibility for each plant to allow for overall performance analysis;
   - Standardized installation of measurement equipment .
   - Revue the biogas plant design for poultry farms.
   - Apply appropriately the existing national gas standards for agro-industrial biogas piping.
   - Systematic and realistic laboratory analysis of bio-slurry; development of an enabling environment through organic fertilizer policy and of marketing strategies.
   - If wastes are recycled in bulk amounts to be converted into energy, this will motivate factories to invest in environmental sound systems.

Recommendations (3/3)

3. Support through policy development the biogas sector growth.
   - Waste and wastewater (pre-)treatment should be mandatory for every factory/ industry/ farm sector.
   - Conduct an in-depth analysis with SREDA selected stakeholders,
     - ❑ discussing recommendations for action plan for sector empowerment, and
     - ❑ discussing proposed road map for market development.
   - Introduce proposed road map 2017-2019.

Additional recommendation from the panel and audience (1/3)

1. Create actual value chain examples with biogas plant, add these as activity in the proposed road map.
2. Use the since 2015 established collaborative partnership with GERBIO and BBDF for training and research on modern biogas development issues.
3. Feedstock could become a value, i. e. rice husk and water hyacinths have rising prices which create serious problem of extending the betterment of biogas or other bioenergies. In this regards government should have a green electricity incentive policy.

Additional recommendation from the panel and audience (1/3)

4. Currently the major problem is with poultry dropping based slurry digestate management in Bangladesh. It needs more improved technology for a better management of poultry drooping based bio-slurry.
5. Install a mixing device inside a big dome digester, such examples should be developed in the road map as activity.
6. How government is managing to issue organic fertilizer certificates to the poultry dropping based slurry, which has a heavy lime content of about 4 to 14% lime stone? This amount of limestone should not be certified as a complete organic fertilizer.

Additional recommendation from the panel and audience (1/3)

7. Promote systematic collaboration with donor agencies which are currently working on bioenergies issues in Bangladesh, because mostly donor agencies are working in their separate and uncoordinated way.
8. Green banking in Bangladesh Bank are ready to sanction the loan for renewable energy components especially in the biogas cases, but they don't have get adequate responses from the entrepreneurs, this may be analysed in depth in the road map.
9. Analyse and show sector wise where biogas is playing a model role in the country, and what are the barriers of extending these sector in the future.

End at 17:30h