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Case study of Thailand, Ghana and Denmark

Lybæk, Rikke; kofi Ackom, Emmanuel; Cudjoe Bensah, Edem

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A review of Biogas application across Continents - Case study of Thailand, Ghana and Denmark

Rikke Lybæk (1), Emmanuel Kofi Ackom (2) and Edem Cudjoe Bensah (3)

(1) Associate Professor, Roskilde University, Department of Environmental, Social and Spatial Change, IMT, Roskilde, Denmark. Tel: +45 46742857, E-mail: rbl@ruc.dk

(2) Senior Scientist, UNEP DTU Partnership, Marmorvej 21, 2100 Copenhagen, Denmark.
Tel: +45 45335289, E-mail: emac@dtu.dk

(3) Department of Chemical Engineering, Kumasi Technical University, P. O. Box 854, Kumasi, Ghana.

Tel: +233 246450842. E-mail: cudjoe.ebensah@kpoly.edu.gh

***Abstract* –** This paper analyses the biogas development within Ghana, Thailand and Denmark to shed light on the different development patterns and future trends that is seen within the biogas sector. Literature review in the form of journal articles and reports is assessed, interviews with agricultural and biogas experts - as well as policy makers within the field of renewable energy - is being conducted. The biogas technology was analysed according to 'historical development', 'feedstock utilization' and 'future development'. As far as the future prospects for the biogas technology the paper concludes, that large public support in the form of governmental grants and development aid has shaped the current platform for the technologies within all three countries, and that continuous support are needed. This is especially required in Ghana, where the need for finance and appropriate policy frameworks are required to move forward. Thailand and Denmark has set up support programs and emphasized on using industrial organic feedstock for biogas production, and Denmark has formulated political targets for utilizing organic household waste as biogas feedstock. For all three countries apply, despite their differences, that large unused feedstock potentials are identified, especially within the agricultural sector (e.g. livestock manure & crop residues), showing that this part of the biogas feedstock must be emphasised more strongly in the future to fully utilize its potentials.

***Keywords* – Biogas, Ghana, Thailand, Denmark.**

1. INTRODUCTION

The biogas technology provides many benefits for society, like e.g. hygienic treatment of solid waste and wastewater, generation of clean energy for heating and electricity, and production of nutrient rich organic fertiliser for agricultural activities, etc. [1]. In developing countries, such as Ghana and Thailand, biogas can serve as a means to reduce the importation of fossil fuels and inorganic fertilizer, increase national energy security, provide clean energy to rural and isolated communities, and create opportunities for youth employment. It also has the potential to contribute significantly to reduction in in-door air pollution (via substitution of wood fuel) and greenhouse gas emissions, thereby contributing to attainment of countries emission reduction targets, and the Sustainable Development Goals 7; thus 'affordable and clean energy' [2].

Many of the advantages of the biogas technology mentioned above are also be obtained in developed countries, like Denmark for instance, as far as e.g. renewable energy production and energy security. In Denmark, the biogas sector was established in the political context of the late 1970'ties energy crisis, and the objective of supporting the implementation of biogas technology was to supply renewable energy and hereby increase the energy security based on indigenous resources. From there on the development of the Danish biogas sector has been widely influenced by Danish public policy [3]. This influence can be seen directly through the governmental funding of development and demonstration programs and indirectly through the framework conditions that was formulated in policy programs, energy plans and environmental protection legislation.

Can a similar development within Thailand and Ghana be identified, where e.g. public support has played a vital role in pushing the technology forward? Thus, what type of development can be identified for the biogas sector within the three countries addressed? And what pathways and development trends can be identified within the countries in relation to e.g. existing and future feedstock utilization?

This paper analyses the biogas development within Ghana, Thailand and Denmark, respectively, to shed light on the different development patterns and future trends, which can be identified for the technology within the countries addressed.

2. METHODOLOGY

The study reported here is based on a review of literature on biogas applications, history and development from numerous reports and journal articles from the selected countries, namely Thailand, Ghana and Denmark. Besides literature the research data also derive from field studies within the countries addressed, as well as expert interviews in the field of biogas energy and policy. We provide an analysis for each of the three countries emphasizing on the following topics:

- Historical developments
- Number of plants, size, and organization
- Use of resources and energy
- Feedstock utilization
- Digestate
- Policy and regulatory framework
- Socio-economic benefits and economy
- Future development

In this short paper, however, we emphasize solely on the 'historical development', the 'feedstock utilization' and 'future development' in our comparative analysis of the biogas sector within the three countries.

3. ANALYSIS

In the following we will analyze the biogas situation in Denmark, Ghana and Thailand following the emphasis as outlined above, thus 'historical development', feedstock utilization' and 'future development':

3.1 Historical development

Denmark:
The Danish biogas sector was established in the political context of the late 1970'ties energy crisis, and the objective of supporting the implementation of biogas technology was to supply renewable energy and hereby increase the energy security based on indigenous resources. From there on the development of the Danish biogas sector has been widely influenced by Danish public policy. This influence can be seen directly through the governmental funding of development and demonstration programs and indirectly through the framework conditions that was formulated in policy programs, energy plans and environmental protection legislation [3]. Thus, the aims and objectives of the programs have been shaped by changing policy regimes, as follows:

In the 1970'ties focus was on energy security following the energy crisis focusing on Farm biogas plants. The early biogas plants were of the plug-flow, -batch and continue operated plant types, of which the latter were selected as future technology concept due to overall better performance. Already in the mid 1980'ties the emphasis shifted from Farm to small scale Centralized biogas plants, the first one being implemented in Vester Hjermitslev in 1984 with focus on reducing nutrient leakage from the agriculture. In the late 1990'ties and the 2000'ties emphasis shifted to large scale Centralized biogas plants, and focus on climate policy, agricultural policy and environmental protection all together.

Public policies have thus been vital for the development of the Danish biogas sector, not only in terms of funding development programs, but also when it comes to shaping the direction of technological choices. Biogas policies have also shaped development of the biogas technology as solutions to e.g. environmental problems related to leakage of nutrients to the aquatics', to the production of renewable energy and to combining these policy objectives [3].

Thailand:
Until mid-1980'ties there were registered around 1,000 biogas plants in Thailand supported by various private organisations, foreign donor aid and by the Thai government, with the Ministry of Public Health, Sanitation Division being a main driver for this development. The technology was based on Chinese fixed dome and floating drum type plants, but relatively fast did the fixed dome plant become the most desirable concept due to a longer life lime and less maintenance compared to other types [4]. The deployment of biogas plants however speeded up in the late 1980'ties, where German technology - facilitated by GTZ/GATE - were adapted and modified to the local context, through the Thai-German Biogas Program.

This was institutionalized in Chiang Mai through the Bio Advisory Unit (BAU) situated at the Chiang Mai University. During the next three decades BAU and Energy Policy and Planning Office (EPPO) under the Ministry of Energy heavily promoted the biogas technology throughout Thailand, focusing both on the BAU biogas technology (rubber tube reactor) and small scale fixed dome brick Farm biogas plants within the agricultural sector.

The Thai-German Biogas Program felicitated the implementation of around 150 large scale biogas plants on pig farms until the beginning of 1990'ties, but estimated that the potential for smaller Farm and household biogas plants were up to 200,000 in five provinces, which unfortunately never has been fully exploited [4]. Today, there are more than 500 larger Farm plants implemented as a consequence of the Thai-German Biogas Program [5]. The biogas potential within the manure-based agriculture in Thailand is, however, still largely unused despite governmental programs, partnerships with donor countries and feet-in-tariff (FIT) schemes and construction grants provided. Especially within dairy and beef farming there are a large potential for biogas technology, as well as within pig and poultry farms.

Biogas production based on waste water treatment from the agro-industry is, on the other hand, widely applied. This is for example the case within sugar mills, within canned tuna and pineapple industries and on starch and ethanol factories, etc. [6]. Within the last years EPPO has emphasized strongly on deploying biogas technology within this sector, to avoid pollution and generate renewable energy from these resources. According to EPPO the production of biogas from industrial waste water treatment has now reached 897 million m3 biogas through 238 supported projects by EPPO [6], of an estimated total biogas potential of 1,000 million m3 annually [7]. This has been promoted by Thai governmental programs where the companies have received grants (up to 10 mill. Bath/company), and other means of support to implement biogas plants [6].

Ghana:
The origin of biogas sector in Ghana can be traced to the 1960'ties [8], and about 10 years after biogas technology was first introduced in Thailand [9]. It took nearly 20 years before the biogas technology was recognised as an

option for improving access to modern energy to the rural poor, owing to stories of the success of the technology in China and India. In a bid to encourage technology transfer to Ghana, the Ministry of Energy sought assistance from China, resulting in the training of some staff at the Ministry and other state institutions at the Biogas Research and Training Centre (BRTC) in Chengdu, China.

In the 1980ties and early 1990ties, the technology was disseminated in cattle rearing communities as demonstration programs, where both dung and night soil were used as feedstock materials (Arthur et. al., 2011). Training and demo programs were also supported by German Appropriate Technology Exchange (GATE) of GIZ (formerly GTZ), Bremen Overseas Research and Development Association (BORDA), and the Catholic Secretariat in Ghana, in the 80ties and 90ties. In 1992, the Ministry initiated an off-grid electrification project comprising ten 50 m^3 digester system fed with dung and faecal matter. The project performed satisfactorily for some years but challenges with ownership, plant operation and maintenance, socio-cultural attitudes against used of faecal-based slurry, and inadequate involvement of women in decision making reduced its potential [8;10]. The project was totally abandoned in the years leading to the extension of grid power to the community in the late 2000nd.

From 2000nd interest from policy makers, as well as financial support from donors for demonstration projects and installations, begun to wane partly due to breakdown of many plants. This resulted in reduction in biogas systems for low income agricultural households, but forced service providers to market biogas solely on business grounds mainly for treatment of black water in wealthy households.

Unlike Thailand, the development and promotion of high-rate digesters for treatment of agro-industrial and industrial waste water and municipal liquid waste has been slow in Ghana. Areas within the agricultural sector such as swine, cattle and poultry farms, slaughterhouses, edible oil extraction and fruits processing, as well as organic municipal/household waste, are promising for large scale dissemination of biogas digesters. The potential of co-digesting municipal waste and various sources of lignocellulosic waste are high.

3.2 Feedstock utilization

Denmark:

Today, Centralized biogas plants in Denmark digest agricultural residues such as e.g. rape oil and seed, soybean, corn residues, wheat straw, deep litter, fruit and vegetables residues, as well as fish wastes, different residues from the food industry e.g. flotation grease, and intestinal contents from slaughterhouses. Again, other plants also digest organic source separated household waste from kitchens and canteens, as for example from the city of Copenhagen. Within recent years some Centralized biogas plants have also started to add different types of agricultural residues (straw, grasses) and energy crops (beet, maize) to increase gas yield.

On Farm biogas plants, the feedstock can also include a mix of organic materials (e.g. grass, beet and maize), deep litter and animal manure, but usually comes from the biogas farm it selves or supplied by neighboring farms [11]. Larges unused biomass feedstock are available for biogas in Denmark e.g. deep litter, cereal straw, clover grass from crop rotation, organic waste from commerce & household, blue biomass (seaweed), which could supplement the scarce organic industrial waste and the use of energy crops (maize, beet) [1].

Thailand:

The feedstock for biogas production in Thailand composes mainly on residues from the agro-industry, being heavily promoted by EPPO. Focus on feedstock within the livestock sector primarily derives from pig manure, whereas poultry manure only very slowly is starting to be utilized as well. Beef and dairy cattle are still rarely kept in stables that facilitate manure collection, but this type of housekeeping could be developed in the future [12], and will allow collection of this feedstock to biogas production and thus limit GHG emissions from the agricultural sector in Thailand.

The estimated manure-based feedstock for biogas production equals 1,060 million m3 biogas annually [7], of which mainly manure from pig farms have been exploited so far, utilizing approximately 17 % of the total manure potential for energy production [13]. It is, however, evident that feedstock from poultry, dairy cow and beef can increase this potential extensively, but require new support schemes from the Thai government, that, as of now, mainly has mainly prioritizes biogas within the agro-industrial sector [14;6]. Also, use of residual rice-straw and MSW could be utilized to boost the gas production on biogas plants, as they are abundant resources in Thailand.

Ghana:

Currently, most small biogas digesters are installed to receive and hygienically treat black water from flush toilets from both domestic and institutional sources. Farm-based installations are few since the cost is usually beyond the affordability of a typical small-scale agricultural household. In places where energy from biogas is prioritised, kitchen and other waste are fed to the digester to increase gas production.

In the industrial sector, palm oil mill effluent (POME), municipal solid and liquid waste, and fruit waste are also used as feedstock in biogas digesters, with the major aim being waste treatment. Farm-based manure from pigs, as well as POME from both small- and large-scale palm oil extractions, are particularly seen as having high potential for development of anaerobic digesters. Small and medium-scale pig farms are the most flourishing of the animal husbandry sector, and their intensive nature makes them more appropriate for the introduction of biogas plants relative to cattle farms. While the potential for anaerobic digestion of poultry manure is high, the housing structure of poultry farms in Ghana need to be modernised to enable collection of manure, unmixed with indigestible bedding materials [15].

3.3 Future development

Denmark:

With specific reference to future developments, biogas will increasingly be upgraded for distribution on the natural gas network in Denmark. Organic household waste and alternative biomass (straw, deep litter, clover grass, etc.) will most likely substitute a large fraction of the industrial waste and energy crops in the future. The biogas sector is indicating that they are working in this direction. A newly development trend is also the implementation of a new biogas concept; Organic Farm plants, where the feedstock originates from e.g. organic dairy farms. On Centralized plants this concept is implemented as a side-line to conventional biogas plant.

In a Danish context, the research pathways in coming years is likely to enhance the utilization of feedstock like straw, deep litter, clover grass and blue biomass (seaweed) to increase the gas yield on Danish biogas plants to secure a sound plant economy. Pre-treatment methods and technologies (hammer mills, extruders, enzymes, etc.) will be included to enhance the digestibility of this feedstock [1]. Also, intensive research efforts will be made to digest organic fractions of household waste to live up to political targets, stating that we cannot incinerate these fractions. Instead they should be re-circulated to farmland to where nitrogen, phosphorous and minerals, on the contrarily, will enhance the soil quality, etc.

Thailand:

For Thailand, more focus could be on feedstock based on livestock manure from beef and dairy in the future - not mainly on manure from pigs, as currently seen. With time, proper handling of the manure and digestate can be applied, supporting the growing of this market in an environmental friendly way; to combine GHG reduction from the agriculture and to produce quality dairy products and beef. Thus, manure from beef and dairy cows could potentially be a new source of feedstock in Thailand for biogas production, but the use of energy crops will also be applied. The Thai government supports the use of this feedstock for biogas e.g. napier grass, and currently an EGAT supported biogas plants feed by napier grass, are being tested in Thailand, from which experience will be gained using this biomass.

Biogas technology connected to the agricultural sector could thus increase in the future, both related to livestock and crop feedstock. We suggest that the use of residual rice straw from Thai agriculture, and MSW from communities as mentioned earlier, should be utilized as feedstock on larger biogas plants to increase the gas yield, to benefit from a high MSW ADDER (FIT) and to re-circulate nutrients. In a Thai context, the future research pathways could revolve about utilization of manure from dairy cows and beef for biogas production, as well as the production of biomass feedstock that could increase the gas yield, e.g. napier grass.

Ghana:

In the case of Ghana, areas within the agricultural sector such as swine, cattle and poultry farms, slaughterhouses, edible oil extraction and fruits processing, as well as organic municipal waste, are promising for large scale dissemination of biogas digesters. The potential of co-digesting municipal waste and various sources of lignocellulosic feedstock are high, as shown in some successful systems currently in operation.

It is, however, necessary for the government in Ghana to create a favourable environment to remove key barriers to the growth of the sector in the future, such as e.g. the high investment cost and lack of flexible financing, difficulties in feeding power to grid from small-scale power producers, weak market for biofertilizer and lack enforcement of laws on discharge of wastewater [15].

4. DISCUSSION & CONCLUSION

The Danish biogas sector has been heavily influenced by public support since the early 1970'ties, and seen, as method to reduce nitrogen leakage from intensive agriculture, to produce renewable energy and to recirculate nutrient, etc. many shifting political regimes have impacted the technology development and dissemination opportunities [3]. In Thailand and Ghana similar public supported programs and aid have been implemented to support the biogas sector.

In Thailand, the development was firstly pushed forward by both governmental grants and foreign donor aid, and especially the Thai-German biogas program speeded up the development within the agricultural based biogas technology. In recent years, however, Thailand has primarily focused its biogas development on the ago-industries, and through national economic support, mainly promoted biogas and digestion of feedstock from this specific sector [6].

Ghana has, like Thailand, received donor aid in order to develop their biogas sector where GATE has been vital organisation supporting biogas dissemination in Ghana. In the initial stage of the development, however, knowledge of biogas technology was transferred from China through training programs, etc. Currently, Ghana face challenge in obtaining donor aid that supports its implementation of biogas technology, especially at household/agricultural level, as many technical issues with the biogas technology has hampered a further development of the sector.

For both Ghana and Thailand apply that more focus should be given to average household/agricultural biogas, as large un-used potential exists within these areas. This also applies for Denmark, where only minor parts of the animal manure are converted to useful digestate (fertilizer) and renewable energy. Only a very limited fraction of the organic household waste is actually digested in biogas plants, and the nutrients re-circulated to farmland in the Danish context.

For Denmark, Ghana and Thailand together applies that more efficient resource utilization (feedstock) needs to be addressed in order to break with this unfavourable development trend. Available feedstock in Denmark can thus be identified within animal manure (poultry, pig, and cow), crop residues (straw, deep litter, grasses), and households (organic sorted wastes). In Ghana residues from agriculture (POME) is huge, just like animal manure (pig, poultry) show the same large potentials as in Denmark. Also, household waste and municipal waste is available in the Ghanaian context.

A similar development trend can be identified in Thailand, with for instance vast amounts of un-used poultry manure and manure from the fast-growing dairy sector [16]. The challenge is here - which also apply for Ghana - to set up manure collection systems within stables etc. to facilitate the utilization of this manure.

In Denmark, new policies and targets are established for utilizing available feedstock, e.g. policies on the use of organic household waste as feedstock in biogas plants [17], and that e.g. 50 % of the animal manure must be digested before 2020 [18]. Although the development and fulfilment of these targets is slow, the policies are formulated and adopted by society.

For Thailand and Ghana new public support or possible donor aid need to focus more on the un-used feedstock potentials, especially within households and agriculture. This will facilitate a utilization of these feedstocks for renewable energy production and recirculation of nutrient providing many benefits for local communities.

Despite the difference between Denmark, Thailand and Ghana, this study reviles, that the type of un-used feedstock for biogas production are somehow similar within the three countries. It is also seen, that the feedstock actually being utilized for biogas production, only account for a small part of the actual available resource, e.g. animal manure, within all three countries.

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