

BIOGAS GENERATION AND RECOVERY POTENTIAL WITHIN SELECTED AGRO-INDUSTRIES AND SOLID WASTE MANAGEMENT SECTOR IN THAILAND

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Abstract : Biogas technology is an efficient way to treat waste and at the same time to mitigate the Green Houses Gas (GHG) emissions through Clean Development Mechanisms (CDM). CDM can be used by industries to comply with the regulations as fixed in the Kyoto protocol and reduce the level of GHG. This study aims at analysing what is the extent of the biogas technology and what are the potential to expand such technology within different selected agro-industries and landfill sites in Thailand. The analysis, based on secondary data collection and site visits, is limited to the generation of biogas from anaerobic treatment of organic wastewater and to Landfill Gas (LFG) recovery. It is found that the recovery of LFG is very limited and may not increase unless the solid waste management system is improved in Thailand. Tapioca, palm oil, rubber industries and distilleries appear to have the greatest potential for biogas generation and recovery mainly due to the large production capacity, which lead to a significant volume of organic wastewater emission. Factories belonging to these industries are big enough for the cost-effective biogas plant implementation. Main hindrances to biogas technology transfer are caused by financial issue having high investment costs and technical issue as the skill and knowledge in biogas technology are not yet widespread in Thailand.

Key Words : anaerobic treatment, biogas, CDM, sanitary landfill, wastewater

INTRODUCTION

Biogas was introduced in Thailand in the 1960s by the Department of Health in Order to cope with rural sanitation issues. At the early stage, application of biogas technologies has been mainly promoted in the households and farms to treat livestock residues. Programs were adopted to demonstrate and promote construction

of family size biogas generation units (fixed dome type) from which biogas was mainly used for cooking and lightning.¹⁾

However, lack of technical knowledge, experience and awareness of farmers and officials led to a disuse and rejection of the technology.²⁾ Special interest from the National Energy Policy Office (NEPO)³⁾ and the Department of Energy Development and Promotion (DEDP)⁴⁾ for biogas application in the agro-industrial sector and landfill sites started in 1995 after a successful partnership between the Deut-

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sche Gesellschaft für Technische Zusammenarbeit (GTZ) and Chiang Mai University in the context of a Biogas Promotion Project for pig farms waste treatment.²⁾ A few projects were initiated to study biogas generation potential from different types of wastewater such as Tapioca, Palm Oil, Slaughter Houses, and Food Industries. The aim of these research projects was to demonstrate the technical feasibility of anaerobic treatment as a means of waste mitigation and energy production through biogas recovery and utilization³⁾. The anaerobic treatment of wastewater presents benefits levels as follows;

- *Operational* : effective way of treatment for high organic loaded stream with high volumetric rate possible and less space required
- *Environmental* : waste stabilization with little sludge production, less odours and Green House Gases (GHG) emissions limitation if the biogas is captured and reused
- *Economical* : low operation and maintenance costs, and savings in energy consumption if the biogas is reused
- *Energy* : production of a valuable source of energy that can be used in replacement of electricity or fossil fuels

Construction of biogas plant or Landfill Gas (LFG) recovery facilities can be a solution for foreign companies, which want to buy CO₂ credits through Clean Development Mechanisms (CDM) from developed countries. These CDM constitute a mean to comply with the regulations in terms of GHG emission reduction as fixed by the Kyoto protocol when energy consumption and air emission cannot be reduced further. For companies willing to invest money in biogas technology and promote CDM in Thailand, it is necessary to investigate what is the current extent of the biogas technology and recovery and especially what are the potential to expand such technologies. No assessment has been made taking into account the anaerobic digestion of agro-industrial solid waste in Thailand. Therefore, the major objectives of this study are (1) to analyse what are the sectors, which have the greatest potential for biogas recovery and (2)

assess the incentives and also obstacles encountered by the industries with the biogas technology to give a critical point of view on biogas technology transfer possibilities. The assessment of the biogas generation and recovery potential in this study is limited to the anaerobic treatment of selected agro-industrial wastewater and landfill leachate and landfill gas (LFG) recover from the landfilling process. The agro-industry categories selected such as Tapioca, Rubber, Palm Oil, Sugar, Pineapple canning, Fish and seafood canning, frozen fish and seafood, brewery and distillery industries are widely developed with a high production capacity per yr.

METHODOLOGY

It was reported⁵⁾ that during the anaerobic decomposition, the amount of methane generated is of 0.35 m³/kg of BOD_L stabilized. This gives a biogas yield comprises between 0.4 and 0.5 m³/kg of BOD_L if the CH₄ content varies from 70 to 90% by volume. More practically biogas yield is generally expressed per kg of COD removed. Thus biogas generation potential and methane recovery within a specific agro-industrial sector can be assessed by the following formula.

$$\begin{aligned} \text{Annual quantity of biogas produced (m}^3\text{/yr)} = & \\ & \text{COD load/yr for the industry category} \\ & \text{considered (kg/yr)} \times \text{anaerobic treatment COD} \\ & \text{removal efficiency (\%)} \times \text{biogas yield} \\ & \text{(m}^3\text{/yr.kg of COD removed)} \quad \dots(1) \end{aligned}$$

$$\begin{aligned} \text{Annual quantity of CH}_4\text{ produced (m}^3\text{/yr)} = & \\ & \text{Annual quantity of biogas produced (m}^3\text{/yr)} \times \\ & \text{average methane content in the biogas (\%)} \quad \dots(2) \end{aligned}$$

The assessment of a practical figure corresponding to an economical feasibility of a biogas plant implementation has been performed. This 'technical availability' of biogas takes into account the possibility for the implementation of a biogas plant within a factory considering the size of the factory and the amount of wastewater to be treated. This is based on the fact that practically, a biogas plant for wastewater

treatment will be cost-efficient and the payback period not too long if the daily loading rate in the anaerobic reactor is not less than 10,000 kg of COD/day. Estimation is based on the following formula.

$$\text{Technical Availability of Biogas (m}^3\text{/yr)} = \Sigma \text{COD load/year (kg/yr)} \times \text{anaerobic treatment COD removal efficiency (\%)} \times \text{biogas yield (m}^3\text{/kg of COD removed)} \dots(3)$$

where only the factories for which the daily production led to a COD load $\geq 10,000$ kg/day are taken into consideration.

Estimation of the COD load/yr for different agro-industries, the biogas yield and assessment of the industry size for practical biogas recovery potential evaluation, follows the framework described in Figure 1. Thus the biogas generation and recovery potential are approached from the different following sources:

- Experimental results obtained from research

teams in different Thai universities

- Databases provided by the Division of In

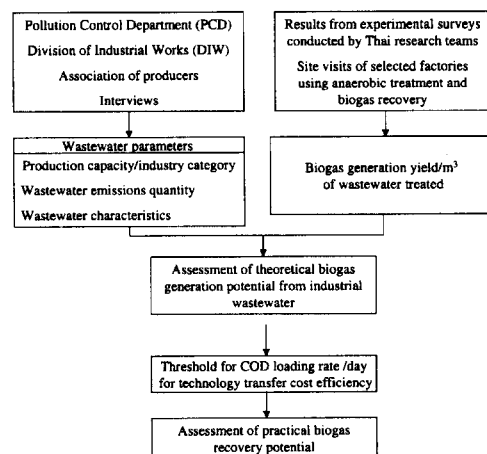


Figure 1. Methodology framework for the assessment of the biogas generation and recovery potential from industrial wastewater in Thailand.

Table 1. Input data for the assessment of biogas generation and recovery potential from anaerobic treatment of industrial wastewater

Industry Category	Production /yr (Unit)	Total number of factories	Wastewater production (m ³ / unit of product)	Total wastewater produced (m ³ /yr)	COD concentration (mg/L)	Total COD load (ton/yr)	Assumed COD removal efficiency (%)	Biogas yield (m ³ /kg of COD removed)	Minimum production capacity for biogas plant investment (ton/yr)	Total number of factories concerned by biogas technology implementation
Tapioca	1,700,000 ton ⁶⁾	53 ⁶⁾	25 ⁴⁾	42,500,000	6,500 ¹⁾	276,250	70-90	0.7 ⁷⁾	16,000	32
Rubber	2,350,000 ton ⁷⁾	200 ⁷⁾	24 ⁸⁾	56,400,000	9,500 ⁸⁾	535,800	70-90	0.5 ⁸⁾	14,000	N/A ⁴⁾
Palm oil	740,000 ton ⁴⁾	49 ⁹⁾	4.75 ⁹⁾	3,512,000	50,000 ⁹⁾	175,600	70-90	0.6 ⁹⁾	10,500	14 ⁹⁾
Sugar	4,982,000 ton ⁵⁾	46 ⁵⁾	12 ⁴⁾	59,784,500	2,500 ¹⁰⁾	149,460	70-90	0.5 ⁸⁾	1,000 ton/day *	30
Pineapple canning	394,854 ton ⁷⁾	22 ⁷⁾	23.5 ⁵⁾	9,279,069	3,759 ⁵⁾	34,889.3	70-90	0.5 ⁸⁾	115 ton/day	N/A ⁴⁾
Seafood/fish canning	512,181 ton ⁷⁾	40 ⁷⁾	20.7 ⁵⁾	10,602,147	3,250 ⁵⁾	34,457	70-90	0.5 ⁸⁾	150 ton/day	N/A ⁴⁾
Frozen fish/seafood	588,683 ton ⁴⁾	N/A	25 ⁵⁾	14,717,075	1,972 ⁵⁾	29,022	70-90	0.5 ⁸⁾	200 ton/day	N/A ⁴⁾
Brewery ¹⁾	1,042,000 m ³	N/A	4.12	4,293,040	2,368	10,166	70-90	0.5 ⁸⁾	1000 m ³ /day	N/A ⁴⁾
Distillery ¹⁾	1,345,340 m ³	17	3.4	4,574,156	25,300	115,726	70-90	0.5 ⁸⁾	116 m ³ /day	N/A ⁴⁾

Sources:

⁶⁾: FINPRO, 2002 ¹⁾: Interview

⁸⁾: COGEN, 2000

¹⁰⁾: World Bank, 1998

⁴⁾: assumed ⁷⁾: Noparat, 2000

⁹⁾: Lawanprasert, 2000

¹⁾: Thai Food Processors Association, 2002

⁴⁾: DEDP, 2002 ⁷⁾: Thai National Rubber Industry, 2001 ⁵⁾: Thai Sugar Mills Association, 2001 ⁵⁾: Computation of data from PCD, 1998 and DIW, 2000

* Only 4 months of production / yr in the sugar industry; Moreover, data regarding wastewater quality are not well defined

Table 2. Input data for the methane inventory model

Data	Bangkok ¹³⁾	Thailand ¹⁴⁾
Population	5,662,499	60,816,227 (year 1997)
Waste generation/capita	N/A	N/A
	Collection rate: 0.59 ton/capita-yr	Collection rate: 0.22 ton/capita-yr
Total MSW collected/yr	3,344,130 ton	13,542,230 ton
Landfilling practice	100% sanitary landfill	72% open-dumping 27% sanitary landfill
Fraction DOC in MSW ¹¹⁾	0.120	0.120
Fraction DOC dissimulated ¹¹⁾	0.770	0.770
Fraction of C as methane ¹¹⁾ :		
-Sanitary landfill	0.550	0.550
-Open dump	-	0.275
Conversion ratio ¹¹⁾	1.333	1.333
Methane recovery	Very low (negligible)	0
Oxidation factor	0 (default value as given by IPCC)	0 (default value as given by IPCC)

Sources ¹³⁾: BMA, 2002,

¹¹⁾: Palanathakumar, 1999

¹⁴⁾: PCD, 2001

dustrial Works (DIW) and the Pollution Control Department to assess the average wastewater quality and quantity emitted

c. Interviews at factories that have already installed anaerobic system or that would be interested to set up a biogas plant.

d. Industry directories provided by producers association

Table 1 summarizes the data collected and used for the calculation of the theoretical amount of biogas that could be generated (Eq. (1)). COD removal efficiency from the anaerobic digestion has been assumed to be between 70 and 90 % based on visits performed during the data collection phase. The biogas yield has been assumed at 0.5 m³/kg of COD removed when no results from experimental survey from Thai local universities were available.

Assessments of LFG emission and its recovery potential have been conducted as shown in Figure 2.

The model used in this study is the Inter-Governmental Panel on Climate Change (IPCC). This model is based on the mass balance approach where no time factor is incorporated and that can be applied to a total waste emanating from the country. The method

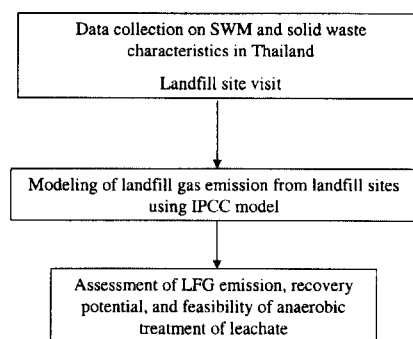


Figure 2. Methodology framework for the assessment of LFG generation, recovery potential and anaerobic treatment of leachate.

assumes that an instantaneous release of methane takes place throughout the year while the waste is landfilled. This assessment is based on:

- Amount of waste generated and type of landfill
- Fraction of DOC (degradable organic carbon)
- Fraction of DOC that is actually degraded into gas
- Fraction of biogas that was released as methane

The IPCC recommends that Municipal Solid Waste (MSW) in open dumping conversion of actual DOC to methane is 50% less the one of

MSW in sanitary landfill This is to distinguish different practices of landfilling

Methane emission from landfill follows the following equation.¹¹⁾

$$\begin{aligned} \text{Methane emission} &= \text{Total MSW (Gg/yr)} \\ &\times \text{fraction MSW landfill} \\ &\times \text{fraction DOC in MSW} \\ &\times \text{fraction actual DOC dissimilated} \\ &\times 0.55 \text{ g C as CH}_4/\text{g C biogas [or 0.275 g if} \\ &\quad \text{open dumping]} \\ &\times \text{conversion ratio (16/12)} \\ &- \text{recovered CH}_4 \\ &\times (1 - \text{oxidation rate of CH}_4) \end{aligned} \quad \dots(4)$$

where, DOC fraction is the proportion of carbon, which can be degraded by micro-organisms in the organic components of MSW and actual DOC is the proportion of carbon in DOC, which is actually degraded into biogas

Because the generation rate data is not available, calculation of biogas generation Potential has been made based on the amount of waste collected The data used as an input for the calculations are summarized in Table 2 Taking a 50% methane content by volume in LFG as an average value¹²⁾ it is possible to deduce the amount of LFG emitted

RESULTS AND DISCUSSION

Current Situation of Biogas Technology Utilization for Wastewater Treatment and LFG Recovery

There are several reasons that make anaerobic digestion and biogas recovery be regarded as a suitable technology for industrial wastewater treatment. First of all, the knowledge, and operation and maintenance skills regarding biogas technology are more and more developed in Thailand ensuring enough technical supports. This comes from the research conducted within different universities, supporting from international organization to promote the technology and existence of few private local contractors. Secondly, the tropical location of Thailand, where the technology can be applied easily as there are no wide variation and drop of tem-

perature that can be limiting factors for the operation of anaerobic digesters. Thirdly, an agro-industrial sector, which is widely developed because of the large extent of certain agricultural crops such as fruit (pineapple mainly), cassava, rubber, palm oil and fishing activities. At the same time the food processing industry gathers more than 1,000 factories throughout the country.³⁾ This leads to the production of a large amount of wastewater having a high organic content, which requires a biological treatment. Finally the production of a valuable alternative source of energy that can substitute to conventional forms of energy (e.g. oil, electricity) and allows reduction of natural resources depletion and pollution-At the same time, a favourable aspect of biogas is that waste treatment doesn't appear as a burden comparing with other energy consuming treatment systems.

Despite these favourable conditions, current development of the biogas technology in the agro-industrial sector is still very seldom. Anaerobic treatment is largely used within factories under the form of anaerobic or stabilization ponds for which no biogas recovery is performed and which are likely not to achieve suitable treatment to comply with emission standards. An examination of database provided by the Division of Industrial Works (DIW) has led to the conclusion that approximately 5% of the wastewater treatment currently installed in Thailand is biogas generation type. Among the industry using such facilities, there is the beverage (brewery and softdrink), fruit canning, frozen seafood, tapioca, snack, dairy, liquor and animal feed industries. Among the existing biogas plant, three technologies are mainly developed:

- UASB (Upflow Anaerobic Sludge Blanket)
- Anaerobic Filter (or Fixed Film Reactor)
- Upflow Anaerobic Contact Reactor

Application of LFG recovery within landfill appears to be an interesting tool (1) to recover energy from waste decomposition and treatment, and (2) to improve the quality of the Solid Waste Management (SWM) system in order to

achieve suitable conditions within landfill sites. Installation of landfill gas recovery facilities might not be seen only as a way to recover energy but also a way to upgrade and optimise the SWM system, preventing open dumping and more generally environmental concerns associated to solid waste. The extent of biogas recovery from landfill site in Thailand is still at an experimental stage. In 2002, only two landfills are partially equipped with these facilities: Kampaengsen and Ratchatewa landfill site that serve the Bangkok Municipality Administration area. In Kamaengsen site, landfill gas installations have been mainly set up for research purposes while in Ratchatewa, facilities have been installed for internal electricity supply at a first stage. Even if the extent of landfill gas recovery is not very broad, there is the sign of interest from the governmental authorities and private companies. The technology will undoubtedly be extended in the future if benefits can be proven.

Biogas Generation, Recovery and Technology Transfer Potential

Regarding the biogas generation and recovery potential, Table 3 presents the results of the calculations conducted from the data presented

in the methodology part. Theoretical and practical gas yield estimations have to be carefully examined as they are very much dependant on the wastewater quality parameters selected for the computation. Four major industries are found to have a great potential in terms of amount of biogas to be generated and possibility of technology transfer. Namely Tapioca, Palm oil, Rubber and Liquor industries benefit from a high level of organic wastewater production resulting in a high rate of biogas potential generation while at the same time the factories are big enough to justify the investments in the anaerobic plant and biogas reuse facility (practical biogas recovery potential). Moreover, the biogas technology is not commonly used in these industries. Thus the potential for technology transfer is 'very high'.

Potential of biogas generation and recovery within the food and beverage industries is found to be very less compared to the previously mentioned categories. First of all the industries considered are smaller and the amount of wastewater generated is smaller too.

Secondly there is a need to perform an assessment case by case, at the factory level as the production capacity and efficiency will vary a lot from one factory to another. Thus, waste-

Table 3 Biogas generation and recovery potential in Thailand

Category*	Theoretical biogas generation potential/yr (million of m ³)	Practical biogas recovery potential/yr (million of m ³)	Possibility for biogas technology implementation		
			Very high	Medium	Very low
Landfill site (LFG 50% CH ₄ content)	1,930	312			✓
Landfill leachate treatment	-	-			
Tapioca	135.4 - 174	111.5 - 143.3	✓		
Palm oil	73.8 - 94.8	43.8 - 56.3	✓		
Rubber	187.5 - 241.1	N/A	✓		
Sugar	52.3 - 67.3	38.9 - 50		✓	
Pineapple canning	12.2 - 15.7	N/A		✓	
Fish/seafood canning	12 - 15.5	N/A		✓	
Frozen fish/seafood	10.2 - 13	N/A		✓	
Brewery	3.6 - 4.6	N/A			✓
Distillery	40.5 - 52.1	N/A	✓		

* : Biogas generation potential from wastewater treatment exclusively except for landfill site

water parameters are not standardised within the category and a wide variation in terms of COD load and amount of wastewater generated can be observed. The potential for biogas technology implementation is 'medium' as some factories are very good target for biogas technology while others are not suitable for it.

In the sugar industry, the factories are producing only 4 months in a year. Production level has to be very high in order for the pay back period not to be too long. Potential for biogas generation and recovery is there but the implementation of the technology might be difficult in certain cases. Other important criteria to consider are the wastewater quantity and quality, which are not very well defined in the sugar industry and make the assessment incomplete. Potential in the brewery industry is 'very low' as the amount of biogas is small compared to other industry categories and the technology is widespread among the brewery in Thailand. Thus there is no real potential for technology transfer.

Practical figure for LFG recovery potential corresponds to the amount of LFG that can be recovered exclusively from the sanitary landfill (27% of the total amount of waste generated only). Even though the amount of LFG that could be recovered is high, such equipment installations suppose a modern and environmentally sound landfill management system, which is far from the current situation in Thailand. Currently, only the two landfills serving the BMA area would be concerned by LFG recovery. In order to increase the potential for LFG recovery, it is compulsory as a first step to upgrade the landfill management system. LFG recovery and its use encounter several technical problems as follows;

- High moisture content of waste
- Vertical wells used for the collection are flooded with water during the rainy season; thus, the use of horizontal well seems to be more appropriate
- Lot of plastic waste in the refuse that are not easily degradable

- Landfill gas recovered has a 100% moisture content and water needs to be removed before further use
- Difficulty to operate a gas engine

All these above-mentioned factors make LFG recovery technology implementation 'very low' even though the amount that could be recovered is very high. There is no potential to generate biogas from leachate treatment in Thailand as the amount of leachate fluctuates a lot following the amount of precipitation throughout the year. Because the amount of leachate is not steady, biogas production from anaerobic treatment would not be steady as well. Thus installation of anaerobic treatment plant for the treatment of landfill leachate is not economically viable.

- Necessity to comply with wastewater standard emissions.
- Interest in energy recovery and savings in energy consumption.
- Interest in selling CO₂ credits in the context of CDM and obtaining significant financial benefits.

However four major limiting factors for the implementation of biogas systems have been found as follows;

- High investment costs
- Difficulties in the operation and maintenance of the digesters if technical support is not provided
- Lack of knowledge regarding energy efficiency and proven financial return of such technologies through CDM
- Lack of efforts from the plant managers in running the system and operation properly

Efficiency and profitability of biogas technologies within industries still need promotion and incentives to be largely accepted in Thailand. Without any technical and financial support it is hard to believe that a factory will select this technology to mitigate the environmental burden associated to its activities. Thus, the demonstration units sponsored by governmental offices such as NEPO or DEDP are prerequisite for technology dissemination. However such promotion campaigns from governmental office appear

weak and not sufficient to drain real enthusiasm among the concerned parties because Thai government seems not to give attractive enough funding at this stage. This is found to be the main hindrance for the implementation of such projects.

CONCLUSION

This study demonstrates that the potential for biogas technology application for wastewater treatment is particularly large in the Tapioca, Palm oil, Rubber and Liquor industries. Biogas generation potential in the above mentioned industries could vary from 50 to 250 million of m³ per yr. These industry categories have a particularly great potential mainly due to the size of the factories that can produce high amount of wastewater sufficient to implement the technology with a pay back period. Application of the biogas technology in food industry shows a promising potential due to its flexibility of size. Recovery of landfill gas represents a large amount of methane and carbon dioxide capture provided that an improvement of the solid waste management system and landfill management is made. Biogas technology transfer still needs to be promoted and sponsored to be largely implemented within the big agro-industries. There are great possibilities for foreign companies to fund CDM projects. Such projects would improve the quality of the end-of pipe treatment facilities and upgrade the environmental performance in Thailand.

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