# Potential for Biogas Producing from Agricultural Waste of Rural Farm in Thailand

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***Abstract*:** *On-farm biogas production facilities typically utilize manure as the main substrate, but other materials such as food processing waste and crop residues can added to increase biogas production. The present paper analyses in the impacts of biogas production on agriculture. The focus is on three aspects: Firstly, on the competitiveness of production activities and waste collections within a farm, secondly on waste compositions and thirdly on the impact of biogas production on farm areas as environmental issues. Annually, organic waste generated from SUT's farm. This showed high organic content in mixed waste for each month as more than 75% of volatile solids. In addition, C/N ratios were sufficient for biogas production as overall values were lower than 20. Various substrate yields biogas in various amounts of organic waste of SUT's Farm in each month. Therefore, methane production potential equivalent to more than 13 tons of LPG, 19 m3 of diesel, 17m$^3$ of gasoline and 38,000 kw-h of electricity in each month, respectively. Very high benefits more 7,200€ or 282,000THB, 17,000€ or 670,000THB, 11,000€ or 433,000THB and 3,800€ or 149,000THB for LPG, diesel, gasoline and electricity equivalent values, respectively. As well as, GHG emission were reducing.*

***Keywords:*** *Biogas Production, Agricultural Waste, Environmental Emissions, Renewable Energy*

## 1. Introduction

Almost kinds of organic waste can be recycled into valuable products according to recent technologies. In designing facilities for the handling, treatment, disposal and reuse of this waste, knowledge of their nature and characteristics is essential for proper sizing and selection of the suitable process. The characteristics of organic waste generated from human, animal, crops and some agro-industrial activities. Pollution caused by these organic waste, and possible diseases associated with the handling and minimization and clean technology presented to emphasized the current trends of waste management. A significant challenge confronting engineers and scientists in developing countries is the search for appropriate solution to the collection, treatment, and disposal the organic waste. Organic waste such as human excreta, wastewater, animal waste and crops wastes contain energy, which may be recovered by physical, chemical, biological techniques, and combination of these. Incineration and pyrolysis of sewage sludge are example for physical and chemical methods of energy recovery from municipal and agricultural solid wastes, respectively. However, these methods involve very high investment and operating costs, which are not yet economically viable. The treatment and recycling organic wastes can be most effectively accomplished by biological process, employing the activities of microorganisms such as bacteria, algae, fungi, and other higher life forms. The by-products of these biological processes include compost fertilizer, biogas and protein biomass.

The potential for biogas production in organic farming is increasing rapidly, although its actual development still lags behind. In 2013, some 114.6 million acers of land were used for organic farming in Thailand [1]. Many organic farmers seem reluctant to invest in biogas production, as the number to have installed the necessary equipment remains proportionally lower than in conventional farming. Consequently, the organic sector is not doing enough to exploit its full potential for renewable energy production. It is still necessary to establish conducive conditions for sustainable biogas production in organic farming. The market analysis identifies suitable entry points from the farmer's perspective. It includes a product definition, a comparative literature study and a survey of organic farmers with and without biogas production.

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Factors that discourage the wider production of biogas on organic farms include the farmers' fears of stressed situations, competition with food or feed production, and possible financial constraints. The competition with food or feed production can be avoided by making a sustainable choice of materials, while training and knowledge transfer (especially the sharing of best practices) can help reduce the level of uncertainty. In some countries (e.g. Bulgaria, Poland and Spain) there is a need to overcome information shortfalls resulting from the relatively low penetration of biogas production and organic agriculture. Technologically and economically sound small biogas plants still have to be developed for use on organic farms. Thus, there is an urgent need for examples of good practice based on small-scale solutions (30-40 kW) – in particular for evidence of economically viable biogas plants integrated successfully in farms' biomass cycles. Organic farming associations, biogas associations and local authorities should cooperate in their efforts to inform the customers. It is also important to achieve greater cohesion between the energy, agricultural and environmental policies of European countries. Legal frameworks (including feed-in tariffs) and state funding should be made more consistent to ensure greater clarity regarding the circumstances affecting organic farmers and their biogas production [2].

On-farm biogas production facilities typically utilize manure as the main substrate, but other materials such as food processing waste and crop residues can added to increase biogas production. The present paper analyses in the impacts of biogas production on agriculture. The focus is on three aspects: Firstly, on the competitiveness of production activities and waste collections within a farm, secondly on waste compositions and thirdly on the impact of biogas production on farm areas as environmental issues.

## 2. Material and Methods

### 2.1. Case Study

The case study was the agriculture farm of Suranaree University of Technology (SUT's Farm). SUT's Farm is a prototype, comprehensive, and standard farm that supports instruction and agricultural research of the university and provides academic services. The farm also serves as a sustainable agricultural and industrial enterprise unit including of crops and animal productions within the area of 1,500 acers as details shown in Table 1 and 2.

TABLE I: Number of animal in SUT's Farm

| Animals | Quantities | Ave. weight (kg) | Waste generation (L/d) |
|---|---|---|---|
| Cow | 335 | 335 | 11,869.3 |
| Pig | 344 | 344 | 2,359.1 |
| Chicken | 7,450 | 7,450 | 1,170.2 |
| Goat | 192 | 192 | 713.5 |
| Sheep | 10 | 10 | 34.2 |

TABLE II: Crops production of SUT's Farm

| Crops | Crops production of SUT's Farm (kg) | | | | | | | | | | | | Annual (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | | | 2017 | | | | | | | | | |
| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | |
| Green bean seed | - | - | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 100 |
| Sun flower seed | - | - | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 450 |
| Corn | 200 | - | 200 | - | - | - | 200 | - | - | 200 | - | - | 800 |
| Sugarcane | - | 101,507 | - | - | - | - | - | - | - | - | - | - | 101,507 |
| Cassava | - | 28,872 | - | - | - | - | - | - | - | - | - | - | 28,872 |

### 2.2. Data Collections & Evaluation

Along with information on farming practices, the waste quantity studies estimated from the recording data of crop production of SUT's Farm and number of animals. Sources of data and methods of estimation were following Polprasert [3]. The analysis physical, chemical and biological characterises of the organic waste is according to the procedures outline of Standard Method for the Examination of Water and Wastewater [4]

## 3. Results and Discussion

### 3.1. Description and Characteristics of the Agricultural Wastes

Annually, organic waste generated from SUT's farm are shown in Table 3. This showed high organic content in mixed waste for each month as more than 75% of volatile solids. In addition, C/N ratios were sufficient for biogas production as overall values were lower than 20. Most of information available has been obtained from studied of anaerobic bacteria. The energy growth of anaerobic bacteria is organic. Nitrogen is utilized for cell structure. To guarantee normal biogas production it is important to mix the raw material in according with proper C/N ratio. Bacteria use up C 25-30 times faster than they used N. Therefore, at this ratio of C/N (25-30/1) the digester is expected to operate at the optimal level of biogas production. However, overall C/N ratios of organic waste from SUT's Farm are sufficient for biogas production every month.

### 3.2. Potential for Biogas Production

Biogas technology can play a vital role in enhancing the socio-economic status of farmers by providing environment friendly and economically beneficial energy from animal dung. Wood, agricultural residue and animal dung are the energy sources for biogas technology. Overuse of fuel wood causes deforestation, consequently, soil erosion, and natural hazards make rural life harder. Biogas technology is simple, uses animal dung, which is readily available in the rural region, as a raw material. Household wastes like wastewater, vegetable peels can also be used as raw materials. Agricultural residues are also a very important source of biogas production. Rice hulls, jute straws, water hyacinth, algae, bran leaves etc. can be used to produce biogas [5]. Various substrate yields biogas in various amounts of organic waste of SUT's Farm in each month which are given in Table 4. Therefore, methane production potential equivalent to more than 13 tons of LPG, 19 $m^3$ of diesel, 17$m^3$ of gasoline and 38,000 kw-h of electricity in each month, respectively. These are sufficient values for overall SUT's Farm energy supply activities.

### 3.3. Values of Biogas

From the environmental point of view, local utilization of biogas for power generation is an extremely competitive alternative in comparison to fossil fuels such as oil and gas. However, the financial aspect of this technology needs to be analyzed to show that the project can also be profitable from the economical point of view. Different aspects of the biogas production, such as equipment costs, lifetime of the system and components, maintenance and operation (O&M) costs, as well as interest or discount rates need to be taken into account. As it was mentioned before, The Table 5 as below shows results of economic studies carried out for the biogas plant based on organic waste from SUT's Farm discussed in the case study. Very high benefits more 7,200€ or 282,000THB, 17,000€ or 670,000THB, 11,000€ or 433,000THB and 3,800€ or 149,000THB for LPG, diesel, gasoline and electricity equivalents, respectively. Also, Muradin and Foltynowicz [6] study shown the biogas plant produced ample profit until the green certificates market collapsed in the late 2012. The net present value of the project's discount rate (of 7.5%) for 2012 was assumed to be a function of interest on outstanding loans. The life of the biogas plant was estimated at 15 years. The project was proven to be financially sound: its NPV amounts to €1,221,213 while its IRR stands at 28%. The repayment period was fixed 15 years. The project was proven to be financially sound: 15 years.

TABLE III. Annually Organic Wastes Generation (tons) and Compositions of SUT's farm

| Wastes | Annually Organic Wastes Generation (tons) and Compositions | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | | | 2017 | | | | | | | | |
| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
| Sugarcane | - | 17.3 | - | - | - | - | - | - | - | - | - | - |
| Sun flower | - | - | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 |
| Cassava | - | 5.8 | - | - | - | - | - | - | - | - | - | - |
| Green beans | - | - | 11.8 | 11.8 | 11.8 | 11.8 | 11.8 | 11.8 | 11.8 | 11.8 | 11.8 | 11.8 |
| Corn | - | - | 236 | - | - | - | - | - | - | 236 | - | - |
| Goat | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Sheep | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Cow | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 |
| Swine | 38.8 | 38.8 | 38.8 | 38.8 | 38.8 | 38.8 | 38.8 | 38.8 | 38.8 | 38.8 | 38.8 | 38.8 |
| Chicken | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 | 17.4 |
| General Waste | 45 | - | 45 | 45 | 45 | - | 45 | 45 | 45 | - | 45 | 45 |
| Total | 85.7 | 108.6 | 85.9 | 85.7 | 85.7 | 85.6 | 85.7 | 85.7 | 85.7 | 85.9 | 85.7 | 85.7 |
| tons/d | 2.8 | 3.6 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Ton-VS | 65.0 | 85.8 | 67.8 | 66.3 | 66.3 | 65.7 | 66.3 | 66.3 | 66.3 | 67.4 | 66.3 | 66.3 |
| C/N ratio | 19.5 | 19.9 | 18.7 | 16.8 | 16.8 | 16.4 | 16.8 | 16.8 | 16.8 | 18.5 | 16.8 | 16.8 |
| %TVS | 75.9 | 79.0 | 78.9 | 77.3 | 77.3 | 76.7 | 77.3 | 77.3 | 77.3 | 78.5 | 77.3 | 77.3 |
| %MC | 50.1 | 58.4 | 61.1 | 58.6 | 58.6 | 63.0 | 58.6 | 58.6 | 58.6 | 65.3 | 58.6 | 58.6 |
| %TS | 50.4 | 41.9 | 39.2 | 41.7 | 41.7 | 37.4 | 41.7 | 41.7 | 41.7 | 35.02 | 41.73 | 41.73 |

TABLE IV. Biogas yields of organic waste of SUT's Farm

| Month | Organic waste generation (kg/month) | Methane production estimation ($m^3$ $CH_4$/Month) | Equivalent Energy | | | |
|---|---|---|---|---|---|---|
| | | | LPG (kg) | Diesel (L) | Gasoline (L) | Electricity (kw-h.) |
| Oct | 85,679.3 | 29,252.20 | 13,456.01 | 19,598.97 | 17,551.32 | 38,027.86 |
| Nov | 108,664.3 | 38,630.16 | 17,769.87 | 25,882.21 | 23,178.1 | 50,219.21 |
| Dec | 85,932.5 | 30,525.80 | 14,041.87 | 20,452.29 | 18,315.48 | 39,683.54 |
| Jan | 85,696.5 | 29,824.95 | 13,719.48 | 19,982.72 | 17,894.97 | 38,772.44 |
| Feb | 85,696.5 | 29,824.95 | 13,719.48 | 19,982.72 | 17,894.97 | 38,772.44 |
| Mar | 85,651.5 | 29,551.05 | 13,593.48 | 19,799.21 | 17,730.63 | 38,416.37 |
| Apr | 85,696.5 | 29,824.95 | 13,719.48 | 19,982.72 | 17,894.97 | 38,772.44 |
| May | 85,696.5 | 29,824.95 | 13,719.48 | 19,982.72 | 17,894.97 | 38,772.44 |
| Jun | 85,696.5 | 29,824.95 | 13,719.48 | 19,982.72 | 17,894.97 | 38,772.44 |
| Jul | 85,887.5 | 30,347.49 | 13,959.85 | 20,332.82 | 18,208.49 | 39,451.74 |
| Aug | 85,696.5 | 29,824.95 | 13,719.48 | 19,982.72 | 17,894.97 | 38,772.44 |
| Sep | 85,696.5 | 29,824.95 | 13,719.48 | 19,982.72 | 17,894.97 | 38,772.44 |

TABLE V. Values of Biogas from Organic Wastes in SUT's Farm

| Month | Values of Biogas | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | LPG | | Diesel | | Gasoline | | Electricity | |
| | Euro | THB | Euro | THB | Euro | THB | Euro | THB |
| Oct | 7,257.80 | 282,037.97 | 17,026.79 | 661,661.23 | 11,151.37 | 433,342.09 | 3,851.81 | 149,681.46 |
| Nov | 9,584.57 | 372,456.48 | 22,485.42 | 873,783.41 | 14,726.38 | 572,267.29 | 5,086.67 | 197,667.83 |
| Dec | 7,573.79 | 294,317.60 | 17,768.12 | 690,469.31 | 11,636.88 | 452,209.20 | 4,019.52 | 156,198.38 |
| Jan | 7,399.90 | 287,560.30 | 17,360.18 | 674,616.63 | 11,369.71 | 441,826.81 | 3,927.23 | 152,612.20 |
| Feb | 7,399.90 | 287,560.30 | 17,360.18 | 674,616.63 | 11,369.71 | 441,826.81 | 3,927.23 | 152,612.20 |
| Mar | 7,331.94 | 284,919.34 | 17,200.75 | 668,421.33 | 11,265.29 | 437,769.25 | 3,891.16 | 151,210.67 |
| Apr | 7,399.90 | 287,560.30 | 17,360.18 | 674,616.63 | 11,369.71 | 441,826.81 | 3,927.23 | 152612.20 |
| May | 7,399.90 | 287,560.30 | 17,360.18 | 674,616.63 | 11,369.71 | 441,826.81 | 3,927.23 | 152612.20 |
| Jun | 7,399.90 | 287,560.30 | 17,360.18 | 674,616.63 | 11,369.71 | 441,826.81 | 3,927.23 | 152612.20 |
| Jul | 7,529.55 | 292,598.46 | 17,664.33 | 686,436.00 | 11,568.90 | 449,567.62 | 3,996.04 | 155285.99 |
| Aug | 7,399.90 | 287,560.30 | 17,360.18 | 674,616.63 | 11,369.71 | 441,826.81 | 3,927.23 | 152612.20 |
| Sep | 7,399.90 | 287,560.30 | 17,360.18 | 674,616.63 | 11,369.71 | 441,826.81 | 3,927.23 | 152612.20 |
| Total | 91,077.0 | 3,539,252.0 | 213,666.7 | 8,303,087.7 | 139,936.8 | 5,437,943.1 | 48,335.8 | 1,878,329.7 |

### 3.4. GHG Emission

Behind the struggle to address, global warming and climate change lies the increase in greenhouse gases (GHG) in our atmosphere. A greenhouse gas is any gaseous compound in the atmosphere that is capable of absorbing infrared radiation, thereby trapping and holding heat in the atmosphere. By increasing the heat in the atmosphere, greenhouse gases are responsible for the greenhouse effect, which ultimately leads to global warming. Biogas is regarded as a climate-neutral fuel since the carbon in the biogas is fixed from atmospheric carbon dioxide, CO2. Biogas consists mainly of methane (CH4), and since methane in itself is a strong greenhouse gas, it is important to gather knowledge about the methane emissions in the form of losses that might occur in the biogas production chain, and subsequently it is important to minimize these emissions. When discussing methane emissions from biogas production, it is important to bear in mind that methane emissions do also occur in natural gas installations.

From the literature study it can be concluded that a number of studies of the methane emissions from biogas plants have been performed in different countries, using different methods and approaches. The large variation in methods makes it hard to draw general conclusions from the existing data. A rather large variation between typical plants in different countries makes the comparison even harder. Reported results of the total methane losses from biogas plants typically range between 1 – 3 % of the produced methane [7].

TABLE VI. Potential for reduction GHG during the biogas production in SUT's Farm

| Month | Methane production estimation ($m^3$/Month) | % $CH_4$ (เฉลี่ย) | ปริมาณ $CH_4$ ($m^3$/เดือน) | น้ำหนัก $CH_4$ (kg/เดือน) | ปริมาณ $CO_2$ ($tCO_2$/เดือน) |
|---|---|---|---|---|---|
| Oct | 29,252.20 | 65 | 19,013.93 | 12,944.68 | 271,838.28 |
| Nov | 38,630.16 | 65 | 25,109.60 | 17,094.62 | 358,987.02 |
| Dec | 30,525.80 | 65 | 19,841.25 | 13,507.92 | 283,666.32 |
| Jan | 29,824.95 | 65 | 19,386.22 | 13,198.14 | 277,160.94 |
| Feb | 29,824.95 | 65 | 19,386.22 | 13,198.14 | 277,160.94 |
| Mar | 29,551.05 | 65 | 19,208.18 | 13,076.93 | 274,615.53 |
| Apr | 29,824.95 | 65 | 19,386.22 | 13,198.14 | 277,160.94 |
| May | 29,824.95 | 65 | 19,386.22 | 13,198.14 | 277,160.94 |
| Jun | 29,824.95 | 65 | 19,386.22 | 13,198.14 | 277,160.94 |
| Jul | 30,347.49 | 65 | 19,725.87 | 13,429.37 | 282,016.77 |
| Aug | 29,824.95 | 65 | 19,386.22 | 13,198.14 | 277,160.94 |
| Sep | 29,824.95 | 65 | 19,386.22 | 13,198.14 | 277,160.94 |

## 4. Conclusions

Biogas technology is valuable technology for waste minimization. Food waste is mainly organic matter, which can be decomposed to valuable energy by biochemical process. It results in two by-products: biogas and digested organic slurry. Biogas produced from anaerobic process is used as fuel substitute for kerosene oil; cattle dung cake, agricultural residues, and firewood. Replacement of firewood with biogas would have a positive effect on deforestation which would improve the neighboring environments, ecosystems and problems with land erosion. Biogas may be utilized for Combined Heat and Power production or for transport fuel production (CH4-enriched biogas). Capturing and using the methane in biogas production also prohibits its release to the atmosphere, where it has 20 times more globalwarming potential than carbon dioxide. In rural areas biogas technology treating human and animal wastes is closely connected with the development of sustainable agriculture, which can rationally balance energy exploration, environmental protection, social progress and economic results. Moreover, it is possible to establish various eco-agricultural patterns linked with biogas suited to local conditions In a number of industrial applications, biogas can be used in small-scale industrial operations for direct heating applications such as in scalding tanks, drying rooms and in the running of internal combustion engines for shaft power needs. It can also be used for steam production. The digestate is a high grade fertilizer. The digested slurry from dung can yield nitrogen which is similar to fresh manure. The nutrient content of digested slurry depends on type of feedstock (manure, co-substrates, etc) digested. Moreover, anaerobic digestion process of organic biomass could transform part of organic bound nutrients to beneficial mineral form.

The application of biogas technology has economic, environmental, health and social benefits. On this background, the challenge for the future appears to be the reconciliation of agro-environmental limitations and energy economics. By keeping this inmind and installing the necessary regulatory framework, it should be possible to exploit the beneficial potential of biogas as a versatile and renewable energy source. Given the respective economical incentives, there is large potential to significantly improve the productivity and stability of AD processes by building on the technological advances that have been summarized above with emphasis on optimization of every single step involved in biogas production and utilization.

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