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Lybæk, Rikke; Sommart, Kritapon

Published in:
GMSARN International Journal

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Lybæk, R., & Sommart, K. (2016). Biogas Application Options within Milk Dairy Cooperatives in Thailand: Case Study Tambon Ban Kor, Khon Kaen. *GMSARN International Journal*, *10*(1), 1-10. Article 10.

Biogas Application Options within Milk Dairy Cooperatives in Thailand - Case Study Tambon Ban Kor, Khon Kaen

Rikke Lybæk amd Kritapon Sommart

***Abstract*—** *By means of a case study conducted within a milk dairy cooperative in Tambon Ban Kor, a district in Khon Kaen Province, this paper analyze opportunities for implementing a biogas development 'hub' in Thailand for achieving bio-economic and environmental benefits within a local rural community. Options for collecting manure and other types of relevant biomass residues within the area are identified. Manure and biomass residues are thus suggested treated in a multi-purpose & centralized biogas plant - the first in Thailand - established in connection to the dairy company, owned by the dairy cooperative, etc. The biogas plant substitutes the use of fossil fuels, and surplus electricity can be exported to the power grid and provide extra income. Local crop farmers and ago-industries could benefit economically from sale of biomass residues to the energy plant. The environment will benefit from e.g. reduced GHG emissions and better manure handling practices, which limits pollution of nitrogen to recipients. Suggestions are provided of how to retrofit the stables to facilitate manure collection, storage and transport to the biogas plant. Which type of biogas plant to implement, financial issues, and potentials for disseminating such biogas development 'hub' to other parts of Thailand, are assessed.*

***Keywords*— Biogas, cattle, milk dairy, cooperatives, renewable energy, bio-economy, pollution, greenhouse gas, ground water, nitrogen.**

1. INTRODUCTION

Energy and agriculture

The energy consumption in Thailand account for 75,214 ktoe annually, of which fossil fuels provides 76.22 %, modern renewable energy 10.94 %, traditional renewable energy 10.94 %, domestic hydro 0.6 % and imported hydro 1.5 %. The energy sector is thus the main source of greenhouse gas emissions (GHG) in Thailand with a highly fossilized energy mix in the commercial electricity generation, composed of 70 % natural gas, 20 % coal and 2 % oil. The domestic modern renewable energy production accounted for 8,232 ktoe in 2013, which corresponds to nearly 11 % of the final energy consumption annually [1]. More than 50 % of the remaining commercial energy is based on imports, which makes the Thai energy sector very sensitive as far as fluctuations in energy prices and availability of energy resources. A transition towards an intensified use of domestic renewable energy sources could therefore benefit Thailand, hereunder the use of e.g. biomass residues from the agricultural sector for production of biogas.

The political targets set forth in the Alternative Energy Development Plan (AEDP 2012-2021) implies, that Thailand should reach a 25 % renewable energy goal before 2021, with biogas providing 600 MW. Under the previous Renewable Energy Development Plan (REDP 2008-2022) the target for biogas was 120 MW, which already was reached in 2011 and stressed the need for more ambiguous biogas targets [1], [2]. Currently, however, the targets for biogas are under revision with a new AEDP being launched in 2015, with the target year being 2036. It is expected that biogas will contribute to 600 MW from digestion of industrial and agricultural waste, and to 680 MW from digestion of napier grass [3], [4]. Thus, in total 1,280 MW before 2036.

The biogas potential within the manure-based agriculture is still relative unexploited, whereas biogas production based on wastewater from the agro-industry is widely applied, for example on sugar mills, within canned tuna and pineapple industries and on starch and ethanol factories, etc. According to Energy Policy and Planning Office (EPPO) the production of biogas from industrial wastewater has now reached 897 million m3 biogas through 238 supported projects by EPPO [5], of an estimated total biogas potential of 1,000 million m3 annually [6]. This is achieved through a program in which Thai companies have received grants and other means of support to implement biogas plants [5].

The estimated manure-based biogas potential is 1,060 million m3 annually [6], of which mainly manure from pig farms has been exploited for biogas production so far, utilizing approximately 17 % of the total manure potential for energy production [7]. In general, however, the Thai government prioritizes biogas within the agro-industrial sector [4], [5]. Thus, large unused potential remains within the livestock sector, especially within pig farms, but also on cattle farms being a fast growing livestock sector in Thailand.

Livestock plays an important role in Thailand as an integral part of farming and rural life, providing food, family income and employment. The global consumption

Assoc. Prof. Rikke Lybæk (corresponding author) is with University of Roskilde, Department of Environmental, Social and Spatial Change, Roskilde, Denmark. Tel: +45 46742857, E-mail: rbl@ruc.dk.

Assoc. Prof. Kritapon Sommart is with University of Khon Kaen, Faculty of Agriculture, Khon Kaen, Thailand. Tel: +66-43-202362, E-mail: kritapon@kku.ac.th.

of animal products is increasing, hereunder dairy products, and Thailand are becoming an important stakeholder on this market with 3,630,725 families being a part of the livestock sector, corresponding to 2.5 % of the GDP that reached 382.46 billion US$ in 2012 [8]. Milk, pork and poultry meat has shown the highest production and consumption growth rates compared to other products. The most important ruminant species in Thailand is still beef cattle that include native Thai cattle, crossbred cattle and a small number of purebred beef type cattle.

Over the last five years, however, beef cattle have fluctuated and now declined with 30.5 %. This is opposite to dairy cattle's that have witnessed an increase of 23 % in the four-year period of 2008 to 2012, from 470,000 to now 58,000 head. The largest population of dairy cattle is in the central region of Thailand where the total milk production is estimated to 968,000 ton per year [8]. Many beef and dairy cattle farmers are organized in cooperatives, where e.g. dairy farmers deliver milk to a local dairy cooperative that treats and process the milk for further distribution.

Problem field

With the increasing dairy cattle farmers in Thailand emerging challenges are how to protect and conserve the environment from e.g. emissions of GHG's (methane & nitrous oxide) to the atmosphere, and leakage of nitrogen to open waters and ground water resources from manure handling. Would it for example be possible to collect, transport and use the cattle manure for biogas production at local dairies, and what resources are available from local agro-industries and local farmers that also could be used for biogas production? Is it possible to cover the energy demands at the dairy companies with biogas from local biomass resources (agricultural residues & manure) to substitute fossil fuels, and which technological options are applicable? Hence, this paper will try to answer whether the increasing milk production in Thailand, on already established and future milk dairies, can undergo a transition in order to provide a more sustainable and efficient milk production chain, with a biogas plant constituting a development 'hub' for bio-economic solutions in rural Thailand?

Purpose of the paper

Through a case study analysis this paper investigates the options for collecting cattle manure from a cooperative of 188 dairy cattle farmers located in Tambon Ban Kor, a district in Khon Kaen Province. The manure is thought digested in a centralized biogas plant - the first of its kind in Thailand - and would be established in connection to the dairy company that are owned by the local dairy farmers being part of the cooperative. The biogas plant could substitute the use of fossil fuels (oil for heat & power from the grid) at the dairy company, and excess heat eventually provide valuable process heat for an extended production at the dairy. Surplus electricity could be exported to the power grid and also provide extra income.

At the farm level investigations of how current manure handling practices are applied among the farmers will be examined, options for collecting manure assessed and which environmental benefits this will lead to as far as e.g. GHG mitigation from the previous handling of manure. Nitrogen leaches to the water environment will most likely decrease, just as emissions of CH4 and N2O from handling of manure will be reduced, due to manure removal. Digested manure can return to farmers as valuable fertilizer increasing the crop yield. Issues like the need for livestock stables to be retrofitted for manure collection, and which incentives farmers see in delivering manure and participating in a centralized biogas plant, will also be addressed.

To increase the gas yield at the biogas plant, manure could be mixed with agricultural biomass residues or organic waste from e.g. local industries (slaughterhouses), local farmers (rice straw, grass), agro-industrial waste (cassava pulp), etc. Thus, a screening of such resources will be conducted to assess these potentials in the case study area. Hence, the community (farmers, agro-industries and other businesses, etc.) would also benefit economically from the biogas facility by supply of biomass residues, which could provide value adding benefits for the local society (less waste for landfill, higher income, more baying power, better environment, less pollution etc.).

Thus, we focus on bio-economy (see Kitchen and Marsden, 2009 [9] & 2011 [10] and Vanholme et. al., 2013 [11]); for how existing systems and technologies can be designed to create value adding activities in a local community, in which dairy farmers and the dairy company collaborate with other local farmers and the agro-industry to utilize existing waste streams (manure) and new (biomass residues from farmers and agro-industry) for increased profit. Also, by expanding the existing production capacity (milk) with added capacity (cheese production & export of electricity), is could be possible to generate extra income locally. The value adding related to renewable energy production will not only be connected to a reduction in the company's dependence on fossil fuels, but also - on the long run - provide a robustness as far as future fossil fuel price increases. Value adding will also be provided by lower environmental pollution in the community, putting less pressure on for example landfill sites, lower emissions of GHG's to the atmosphere and less spill of nitrogen to water environments, etc.

2. METHODOLOGY

Empirical data utilized in this paper was collected during a period of two weeks in March 2015, comprising of a) Field data collection during a four days study tour in Khon Kaen/Tambon Ban Kor, b) One day visit to Pakchong in Korat, and c) Seven days of interviews in Bangkok with energy/biogas experts, policy makers, technology manufacturer, etc. Table 1 below outline from whom and where the empirical data from Thailand origin, and what type of information is provided.

Apart from the stakeholders mentioned above several Danish organizations has been contacted in order to discuss the findings in Thailand, and to assess a transition of the milk dairy production in Tambon Ban

Kor. These stakeholders are listed below:

- Niels Østergaard & Michael Støckler. Special consultants, Plants and Environment (Experts in biogas). SEGES P/S, Agro-Food Park 15, 8200 Aarhus. Denmark.
- Helge Kromann. Special consultant, Livestock (Expert in livestock housekeeping, stable designs, collection of manure, etc.). SEGES P/S, Agro-Food Park 15, 8200 Aarhus. Denmark.

Semi-structures qualitative interviews were thus conducted with the stakeholders outlined above and genuine observations applied in the field [12]. Besides the empirical data we have assessed journal literature, background reports/statistics on agriculture and energy in Thailand etc. to triangulate data and information given through interviews/observations [13].

Table 1: Informants in Thailand

Who	Organisation	Name	Where	Info
Researcher	Animal Nutrition Research Development Centre	Dr. Krailas Kiyothong	Pakchong, Nakornrachasima	Napier grass for biogas and cattle feed, Growing and harvest opportunities
Four farmers	Tambon Ban Kor Dairy Cooperative	Farm # 1-4	Tambon Ban Kor	Dairy cattle house-keeping, Stable designs, Manure handling practices, Environmental issues, Incentives to join biogas plant
Khon Kaen Dairy cooperative	Tambon Ban Kor Dairy Cooperative	Company board (10 members)	Tambon Ban Kor	Energy & mass balance, Milk prod., Total capacity, Waste water prod. & treatment, Incentives to join biogas plant
Cassava company	Kansiri Starch co. Ltd.	Mr. Photjanart Haungsakul	Phrayuen District	Ago-industrial residues for biogas prod., Availability, Price
Rubber learning center	Khon Kaen office of the rubber replanting aid fund	Mr. Thum Nilsuvan	Khaosuankwang District, Khon Kaen Province	Ago-industrial residues for biogas prod., Availability, Price
Investor/ Developer of renewable energy	ENSOL Creative Energy	Mr. Somkiat Sutiratana	Bangkok	Financial opportunities, Capacity building, Relevant biomass residues for biogas
Consultant	ECN	Lars Møller	Bangkok	Relevant biomass residues for biogas, Technical options
Consultant	Danish Energy Management Thailand	Karsten Holm	Bangkok	Relevant biomass residues for biogas, Technical options
Energy policy authority	DEDE	Ms. Karnnalin Theerarattananoon & Ms. Jintana Laoruchupong	Bangkok	Relevant biomass residues for biogas, Technical options, Policy goals & support for biogas, Grants & FIT
Technology manufacturer	TBEC	Mr. Pajon Sriboonruang & Mr. Lars Gustaf Godenhielm	Bangkok	Financial opportunities, M&O, BOOT, Collection of manure & logistics, Capacity building
Energy policy authority/ Researcher	EPPO/Chulalongkorn University	Mr. Chaiwat Pollap	Bangkok	EPPO biogas program in industry, Grants & support to biogas, Biogas potentials in Thailand in sectors

The paper now proceeds with a presentation of the empirical data obtained through local farmers in Tambon Ban Kor, as far as livestock housing practices, manure handling and environmental issues etc., where after a screening of relevant biomass residues are conducted for the case area. Data from the dairy company are also presented in order to assess, whether biogas can substitute the use of fossil fuel at the plant, etc. Finally, a conceptual layout of the biogas plant as a development 'hub' - for bio-economic value adding benefits within Tambon Ban Kor and nearby area - are presented based on the empirical data. Hereafter, opportunities for deploying such biogas development 'hub' will be further discussed in the chapter that follows. A conceptual figure of the biogas development 'hub' generated from empirical data, is depicted in Figure 6 at the end of chapter 3.

3. CASE STUDY: TAMBON BAN KOR AND NEARBY AREA

Dairy cattle farmers

The data below are provided from farmers and through information obtained from the dairy company, and from a small survey conducted by Khon Kaen University on this topic [8], as well as from field study observations. Four out of 188 dairy cattle farmers (2,926 milking cows and 4,106 calf and heifers for breeding replacement cattle), who participate in the milk cooperative in Tambon Ban Kor, were thus visited during the field study tour. Only small variation between the four farms was identified, mainly consisting of two farmers growing napier and ruzi-grass for cattle feed and another having a malfunctioning turbular biogas digester substituting the use of LPG for cooking purposes. The situation is quite similar on the 184 remaining farms [8].

Number of cattle's & milk production (Farm #1-4)

In total, each farm holds between 34 and 53 cattle's, whereof 17 to 24 (approximately half) were dairy cattle and the remaining calf and heifers for breeding replacement cattle. The average milk production added up to 14 litre milk/head/day.

Feed & water usage (Farm #1)

Wastewater from a nearby brewery (yeast), rice-straw (25,- bath/bale), cassava pulp (200 bath/ton). (Farm #2) Use napier grass from own fields (fertilized with own dried manure), cassava-pulp and rice-straw. Water is provided by a 40-meter deep pump that supplies water to the cattle (not human). (Farm #3) Rice-straw, cassava-pulp and cassava-peel (200 bath/tons). (Farm #4) Rice-straw, cassava-pulp, ruzi-grass from own fields (fertilized by own dried manure). Water supply provided by a 70-meter deep pump.

Stable design & manure management (Farm #1-4)

Half of the stables were designed with cement flooring and another half with soil flooring (hence no real flooring). The manure was piling up and the cattle's were walking in a 10-30 cm layer of manure (solid and slurry), as shown in Figure 1. When the manure reaches a certain level it is removed from the confinement area to the grass area just besides and dried in the sun, illustrated in Figure 2. All farmers sell dried manure to other local farmers in 15 kg bags at a cost of approximately 30 bath per bag (2,000 bath/tons). (Farm #1) As an example the total income from sale of 2.500 bags of manure added up to 75.450 bath on an annually basis.

Fig. 1: Soil-flooring stable.

Fig. 2: Manure drying in sun.

Environmental issues (Farm #1-4)

Spill of slurry (liquids) to the surrounding environment in the confinement area, where the cattle's is situated, was observed, leading to possibly surface water and ground water contaminations. Also, spill of liquids (manure, cleaning water) from cleaning and milking the dairy cattle's, was observed. This wastewater is simply distributed in small outlet canals to the grass areas just besides the confinement area. See Figure 3 below.

Fig. 3: Manure & cleaning water outlet.

Energy usage (Farm #1)

The farm had a mal-functioning biogas plant (turbular design) to produce biogas for cooking, which substitutes LPG in the kitchen. Solid manure and water are thus supplied to the biogas plant. When operating it produces more energy than can be utilized within the household, meaning that surplus methane gas is more or less realized to the environment on a constant basis.

The dairy company

Empirical data are from the dairy company visit, including a board meeting where the biogas ideas were presented by the authors of this paper. Thus, data is from interviews with two of the board members, a tour inside the company and from observations.

Energy use & process description

26,660 litre of diesel oil are utilized annually for process heat purposes (total 800,000 bath/year), and 240,000 kWh of electricity are consumed on an annual basis mainly to provide for cooling services (total 1,200,000 bath/year). The boiler temperature are below 80 degree C. (74-77 degrees C. normally), and are utilized by means of a heat exchanger to heat up and pasteurize the milk. The milk is heated in 16 seconds, and hereafter immediately cooled down, and then stored in large vessel tanks at eight degrees C. Then, the milk is packed is smaller packages and stored at eight degrees in maximum three days.

Milk input & output

38 tons of raw milk per day is supplied from the 188 dairy farmers connected to the cooperative, whereof 20 ton is processed at the company and the remaining 18 ton sold to other dairies. Thus, 20 tons are being processed at the dairy, but the actual capacity is 30 ton. Milk that equals 6.1 million litre (or 6.000 tons), on an annual basis, are thus produced and distributed as school milk to the Khon Kaen and Northeast of Thailand. The dairy would like to expand their milk production with a production-line of cheese also, in order to utilize all the raw milk supplied, and to be able to operate all year round through the new market opportunities that such cheese production could provide.

Operation period

The dairy operates everyday (except Friday) from 8 am to 5 pm (lunch close-down from 12 noon to 1 pm; thus 1 hour). Currently the dairy provides jobs to 54 staff members. It is closes down in March/April (45 days) and in October (15 days) due to school holidays.

Wastewater generation

Wastewater ads up to 20 m3 per day, hence 20 tons of milk output equals 20 m3 of wastewater. Wastewater treatment is applied by means of two tanks, where fat is separated and skimmed within both tanks. Finally, the wastewater is send to an open reservoir/lagoon. Skimmed fat (sludge) is utilized at the dairy to fertilize trees and vegetables. The wastewater from the dairy company could however be utilized for biogas production, and the open smelly lagoon be avoided (see Figure 4).

Biogas options?

With the temperature requirement identified within the dairy company, the amount of energy needed and the plans for expanding the production with a production-line of cheese, it is viably to implement a biogas plant in connection to the dairy. Currently, there is a production gab in the operation period due to school holidays in which no heat is needed, but if the production is expanded with a cheese line, the dairy could operate full time and heat would be required on a constant basis.

Biomass from farmers

The data below is from interviews in Bangkok, from field trips to Pakchong and Tambon Ban Kor, where a napier grass expert and the dairy cattle farmers were visited respectively.

Fig. 4: Wastewater from the dairy in Tambon Ban Kor.

Napier grass

Napier grass (a sort of fast growing elephant grass) is relatively costly as animal feed compared to rice-straw, cassava-pulp and peel, if not grown on the farmer's own land [14]. Unless the production and harvesting is provided by highly commercial and technological advanced methods, which is slowly being deployed in Thailand [15], it will hardly be viably for biogas production (see Figure 5).

Fig. 5: Napier grass ready as livestock feed.

Farmers are willing to pay a higher price for napier grass as animal feed, compared to what energy facilities are willing to pay (3,500 vs. 1,500 bath per tons respectively) [14]. Thus, we suggest that the green napier top could be used for animal feed, as currently practiced, and that the lower straw can be utilized for energy production. This would however require a pre-treatment, e.g. a macerator or a shredder to open up the fibres [15]. It is, however, pivotal to prioritize the use of nutrition rich napier grass as animal feed to increase the yield of milk from Thai dairy cattle. 14 litres of milk/day/head is very low compared to e.g. Denmark, where dairy cattle's in average provide 30 litre/day/head [16], [17].

Rice straw

Rice straw is available within the Khon Kaen area and is a valuable biomass residue for dairy cattle farmers and currently utilized as bedding material, but primarily as fodder. Straw is also beneficial for biogas production and can increase the gas potentials significantly, but require a longer retention time to be fully digested [18]. Thus, feeding the biogas plant with rice straw from the local community can benefit the gas yield, and provide extra income for rice farmers [19].

Cassava

Not only the cassava root is appropriate for biogas production, but also the remaining root system (cassava rhizome) and top, which currently are disposed of by means of e.g. field burning or natural degradation [19]. This type of biomass residue is widely distributed in the Khon Kaen area, due to the high concentration of cassava-starch companies in the region (Ibid.). To increase the dairy cattle milk yield, we suggest utilizing raw cassava root for concentrate feed, and in addition for production of starch.

Biomass residues from agro-industries

The data provided below, is from interviews in Bangkok and field trip to Khon Kaen area, where a cassava industry and rubber learning center were visited.

Cassava residues

Numerous cassava companies are established in the Khon Kaen area and generate vast amounts of cassava-pulp and peel residues. Within the cassava company visited they processed raw cassava equal to 800 tons per day that provided 200 tons of starch, but also by-products equal to 600 tons (peel and pulp), not including very high quantities of wastewater. The company was in the process of finalizing a large Chaing Mai-biogas reactor to digest the company's wastewater, and hereby substitute the use of oil for heat generation [20]. Depending on the price of pulp and peel the company would sell all its residues for energy production, if the biogas plant pays more than farmers (Ibid.).

Pulp and peel could, however, also be utilized as livestock feed (see Figure 6), but the quality is not as good as napier silage grass, so if surplus pulp and peel residues exists, it would be beneficially be supplied to biogas plants [14]. The wastewater could be treated on site at the company to facilitate the use of generated heat in the processing of starch. Thus, supply of cassava residues to the biogas plants would both come from the starch company, as well as from local farmers supplying roots (cassava rhizome) and top to the energy facility.

Rubber residues

Rubber processing industries is widely distributed in Khon Kaen Province and Northeast of Thailand. The wastewater is currently not utilized for biogas production, but simply discharged or sometimes dried and used as fertilizer [14]. But the content of the wastewater can be valuable for energy production, as it contains protein, sugars and natural nitrogen, which makes it appropriate for biogas production [14], [21]. At the individual farms it is difficult to utilize the wastewater for biogas, as the production is relatively small. Farmers press liquid out of the rubber, but it is difficult to collect these relatively small amounts of residues. At the industrial level, however, this can relatively easy be applied. Around 30-40 % of the rubber is liquids and by a mechanically presser it is possible to press and collect this wastewater on an industrial scale. Thus, such rubber wastewater could be supplied to the biogas plant and increase the gas yield extensively [14].

Biomass residues from other types of industries

Within the Tambon Ban Kor area are also situated a large brewery company (Singha-beer), from where yeast could be supplied to the biogas plant if surplus residues exist, and thus not being used as animal feed. Other relevant types of industries could be slaughterhouses, fish industries and other types of food industries that produce clean biomass residues. It could also be local vegetable markets that generated organic waste currently being collected and simply landfilled [22].

Organic waste from MSW and wastewater treatment 200 tons of municipal solid waste (MSW) is collected every day from Tambon Ban Kor, but currently not source separated. It goes however directly to landfill, but the potential for collecting the organic fractions is an opportunity. Wastewater treatment is not applied within rural areas in Thailand, only within larger cities [19], but certain companies are likely to treat their wastewater on-site, due to environmental regulation, and the sludge could thus be supplied to the biogas plant, e.g. from food and fodder manufactures, etc.

4. DISCUSSION AND CONCLUSION

Manure collection

The empirical data expose that it is difficult to collect manure for biogas production at the dairy cattle farmers in Tambon Ban Kor, as the existing stables are inappropriate for this. Manure could however be collected by means of man-power (shovel and buckets), but farmers do not have spare resources for such activities and would still need appropriate storage capacity. Thus, the stables need to be retrofitted in order to efficiently collect and store manure, where after it could be collected by truck once a week and transported to the dairy company. Hereafter it could return to the farmers as a good quality fertilizer with a higher value (income, crop yield), or be distributed from the biogas plant to crop farmers. With an expanding milk dairy sector, within a shrinking spatial area, it is pivotal that Thailand modernizes their dairy cattle stables in order to enhance the milk quality and yield per cow, and emphasise on the environmental consequences of dairy production in the future.

We suggest that farmers implement new stables designed similar to the concept known as 'cow kennel' [23]. The stable is designed with concrete flooring in two levels. The dairy cows are provided a dry rest-area from where manure (solid waste and slurry) are dropped to a central pathway, and the manure collection facilitated by means of a 1.5-2 degree slope towards the centre of the pathway.

In the centre of the pathway a canal in the floor - established with PVC pipes - secure a fast collection of liquid slurry. In this way emissions of ammonia in the stable area are avoided, and a fast collection of liquids to the manure storage tank provided. Collection of solid waste is done along the pathway mechanically by means of a scraper - run e.g. by an electrical motor - or manually by a hand-operated scraper pushing the manure in front of the machine. Besides the rest-area the dairy cattle have feeding and milking areas [23], [24].

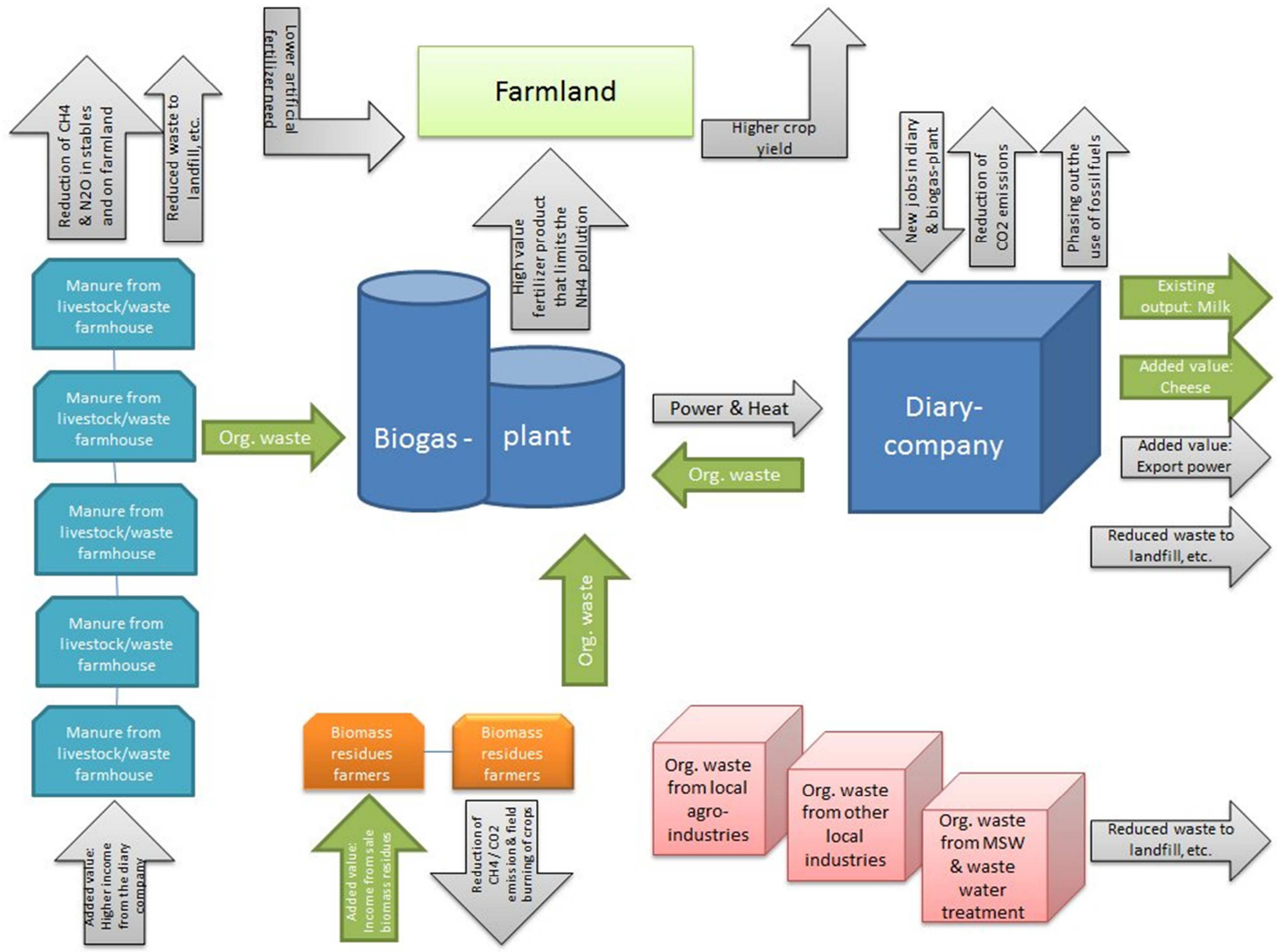

Fig. 6: Biogas development 'hub'.

Such stables provide relatively low-cost technical solutions to manure collection, and add up to approximately 1,000 Euro per cow per head [23]. This is the estimated cost price in a Danish context, which would be relatively lower in a Thai situation when manufactured locally using Thai craftsmen.

Use of biomass residues

As opposed to the collection of manure the empirical data show, that various biomass residues are available for biogas production, which could provide environmental benefits as well, due to e.g. less landfilling, burning and natural degradation of agricultural residues on the fields, which causes various problems. Especially wastewater from rubber trees, residues from cassava roots (rhizome) & top, pulp and peel, various organic wastes from food industries & sludge from wastewater treatment, as well as rice straw, are appropriate for biogas production. The biogas plant can initially be supplied with this type of feedstock and then later - when stables are retrofitted - be supplied with manure from dairy cattle farmers in Tambon Ban Kor and other types of ‘difficult’ waste, e.g. sorted organic household waste (see below).

Thus, the identified biomass are agricultural residues and manure mixed with straw (bedding material and rice-straw), different agricultural residues, wastewater and sludge from the dairy and local industries. Manure and organic household waste can be supplied at a later stage when stables are retrofitted and source separation of municipal waste applied. Around 200-220 kWh of electricity and 350 kg of declared sanitized compost fertilizer can in average be generated from each ton of biodegradable feedstock delivered to the biogas plant. Digested manure will provide up to 2,500 bath/ton [14], which is compatible with the existing prices.

Biogas technology and ownership

The biogas plant should be designed at a CSTR-digester based system (Continuously Stirred Tank Reactor) [4], [25], [26], including the necessary auxiliary unit operations to receive and handle the above mentioned types of agricultural residues, etc. Thus, the equipment includes concrete platform for intermediate storage of the different types of organic wastes, chippers for rough waste and choppers for particle size reduction in mixtures of liquid and solid animal manure, chipped rough waste and other wastes, besides a separation system for production of reject water from the digested substrate.

The reject water should be used to dilute the incoming waste to a proper dry matter level, making it a proper fluid, which may be handled and treated in the CSTR digester [16]. The system may resemble the coming biogas plant at Tup Sakae, designed by Green Energy Network and SEGES. Thus, the technology is already available in Thailand and may only include minor principal changes and added unit operations to cope with the demands of this actual set-up (Ibid.).

In contrast to other biogas technologies implemented in Thailand owned by one single person/family at farm or industrial scale level, the suggested biogas plant will be jointly owned by several stakeholders, constituted by the dairy cooperative (dairy company and farmers). We suggest, however, to also including other relevant stakeholders in the local community to become partners of the biogas plant in order to facilitate a broad local ownership. This could be local authorities, e.g. Ban Kor Municipality, Khon Kaen Province or agro-industries supplying biomass residues to the energy plant.

Stakeholder incentives (farmers & dairy company)

According to the empirical data farmers in Tambon Ban Kor would like to poses better and more modern stables with more cattle’s that also could facilitate a collection of manure. Farmers would like to deliver manure to the biogas plant, but are keen on getting digested manure back as it currently provides extra income. At the dairy company and expansion of the production with a cheese line requires more energy, and thus more fossil fuel uses. The company would like to cover the energy needs by renewable energy contributing to less GHG emissions, but the main incentives for implementing a biogas plant is to modernize the manure handling practices at the farm level. Pollution from leakages of nitrogen to water environments etc. is a great concern.

Financing

The dairy company is concerned whether they can borrow money to invest in the biogas plant, and how it could be operated. If not financed by the dairy company, it could be established as a Build Operate Own and Transfer (without the transfer part) BOOT-project financed through funding by developing countries [27]. Traditional bank loan for renewable energy projects in Thailand is usually difficult. The dairy company would then lease the operation and maintenance of the plant, which would be provided by an external company (Ibid.). When established, it will be the first of its kind (a multi-purpose & centralized biogas plant) in Thailand, co-funding could eventually be provided by the Thai Governmental, through the ENCON Fund by EPPO and DEDE [4].

Development ‘hub’ (local benefits)

Knowledge and experiences from this case study and pilot plant, if established, can be disseminated to other farmers in Thailand. Currently, 7,000 cattle (beef & dairy cattle) cooperatives exist, whereof many are milk dairy cooperatives. The many benefits obtained by the biogas development ‘hub’, is illustrated in Figure 6. To facilitate analysis of the options for applying such beneficial system in other Thai contexts, we suggest utilizing this conceptual figure to be able to identify appropriate farmers, ago-industries etc. for supply of biomass residues for such development ‘hub’.

REFERENCES

[1] Department of Alternative Energy Development, DEDE (2014). *Thailand Alternative Energy Situation, 2013*. Ministry of Energy, Bangkok, Thailand. ISSN: 1686-5170.

[2] Siteur, Joost (2012). Rapid deployment of industrial biogas in Thailand: Factors of success. Chapter 6 in

The role of financing to improve industrial efficiency. Proceedings to the ECEE 2012 Summer study on energy efficiency in industry. Available at: http://proceedings.eceee.org/visabstrakt.php?event=2&doc=6-037-12.

[3] Theerarattananoon, Ms. Karnnalin (2015). DEDE, Interview, Bangkok the 5/3/2015.

[4] Laoruchupong, Ms. Jintana (2015). DEDE, Interview, Bangkok the 5/3/2015.

[5] Pollap, Chaiwat (2015). National Energy Policy and Policy Office & EPPO / Chulalongkorn University, Interview, Bangkok the 3/3/2015.

[6] Aggarangsi, P., Tippayawong, N., Moran, J.C., Perkkriangkrai, P. (2013). Overview of livestock biogas technology development and implementation in Thailand. In *Energy for Sustainable Development.* Vol. 17, p. 371-377. International Energy Initiative, Elsevier Inc., UK.

[7] Chaiprasert, P. (2011). Biogas production from agricultural wastes in Thailand. In *Journal of Sustainable Energy & Environment*. Special Issue (2011), p. 63-65. JSEE, Bangkok, Thailand.

[8] Sommart, Kritapon (2014). Research paper titled: Current manure management practices of livestock farming in Thailand. Khon Kaen University, Faculty of Agriculture, Khon Kaen, Thailand.

[9] Kitchen, Lawrence and Marsden, Terry (2009). Creating Sustainable rural development through stimulating the eco-economy: beyond the eco-economic paradox. In *Sociologia Ruralis*. Vol. 49, nr. 3. Blackwell Publishing, Oxford, UK.

[10] Kitchen, Lawrence and Marsden, Terry (2011). Constructing sustainable communities: a theoretical exploration of bio-economy and eco-economy paradigms. In *Local Environment*. Vol. 16, nr. 8, p. 753-769. Routledge Taylor and Frank Group, UK, ISSN: 1354-9839.

[11] Vanholme, Bartel, Desmet, Tom, Ronsse, Frederik, Rabaey, Korneel, Breusegem Van, Frank, De Mey, Marjan, Soetaert, Wim, Boerjan, Wout (2013). Towards a carbon-negative sustainable bio-based economy. In *Frontiers in plant Science*. Plant bio-Technologies. Vol. 4, article 174. Lucerne, Switzerland.

[12] Kvale, Steiner (1997). *Interview - En introduktion til det kvalitative forskningsinterview*. 1.udgave. Hans Reitzel Forlag. Copenhagen, Denmark. ISBN: 87-412-2816-2.

[13] Yin, Robert K. (2003). *Case study research - Design and methods.* 2 edition. Sage, Thousand Oaks. New Delhi, New York.

[14] Møller, Mr. Lars (2015). ECN. Interview, Bangkok the 5/3/2015.

[15] Kiyothong, Dr. Krailas (2015). Animal Nutrition Research Development Centre, Interview, Pakchong the 4/3/2015.

[16] Østergaard, Niels (2015), Interview, Skejby the 24/4/2015.

[17] Støckler, Michael (2015), Interview, Skejby the 24/4/2015.

[18] Lybæk, Rikke (2014). *Development, Operation, and Future Prospects for Implementing Biogas Plants - The case of Denmark.* In Use, Operation and Maintenance of Renewable Energy Systems: Experiences and Future Approaches. red./M.A. Sanz-Bobi (ed.). Vol. 111 Switzerland: Springer Publishing Company, 2014. s. 111-144 (Green Energy and Technology). DOI: http://dx.doi.org/10.1007/978-3-319-03224-5_4.

[19] Sutiratani, Mr. Somkiat (2015). ENSOL Creative Energy. Interview, Bangkok the 7/3/2015.

[20] Haungsakul, Mr. Photjnart (2015). Kansiri Starch Co.Ltd. Interview, Phrayuen Districh the 11/3/2015.

[21] Nilsuwan, Mr. Thum (2015), Rubber learning centre. Interview, Khaosuankwang District, Intervoiew Khon Kaen Province the 11/3/2015.

[22] Ali, Ghaffar, Nitivattananon, Vilas, Abbas, Sawaid, Sabir, Muazza (2013). Green energy to biogas: Renewable energy possibilities for Thailand's green markets. In *Renewable and Sustainable Energy Reviews*. Vol. 16, p. 5423-5429. 2012 Elsevier Ltd., UK.

[23] Kromann, Helge (2015), Interview, Skejby the 24/4/2015.

[24] Dansk Landbrugsrådgivning (2008). Landscentret, Plan og miljø, landbrugets byggeblad, Århus, Denmark.

[25] Luostarinen, Sari, Normak, Argo, Edstrøm, Mats (2011). *Overview of biogas technology.*Baltic Forum for Innovative Technologies for Sustainable Manure Mnagement, Baltic Manure, EU baltic Sea region EU program 2007-2009. EU.

[26] Nasir, Ismail M., Mohd Ghazi, Tinia I., Omar, Rozita (2012). Anaerobic digestion technology in livestock manure treatment for biogas production: A review. In *Engineering in Life Sciences.* Vol. 12 Nr. 3, p. 258-269. Wiley-VHC Verlag GmbH & Co. KGaA, Weinheim, Elsevier Inc., UK.

[27] Sriboonruang, Mr. Pajon (2015). Biogas technology and business model developer, TBEC. Interview. Bangkok the 3/3/2015.