CASE

Combined heat and power from agro-industrial wastewater (TBEC, Bangkok, Thailand)

Louis Lebel and Krishna C. Rao

Supporting case for Business Model 8	
Location:	Bangkok, Thailand
Waste input type:	Wastewater from agricultural industries (starch, palm oil and ethanol)
Value offer:	Build, Own, Operate and Transfer (BOOT), one-stop shop to treat agro-industrial effluent and generate electricity from biogas and CER certificates
Organization type:	Private
Status of organization:	Founded in September 2003
Scale of businesses:	Large – TBEC has processed 6,200,000 m^3 of wastewater/year, generated 38,360,000 Nm^3 of biogas/year, and 26,500,000 kWh of electricity/year by multiple projects
Major partners:	The Private Energy Market Fund (PEMF), Finland and Al Tayyar Energy (ATE), Morocco (Head office in the United Arab Emirates) (provided investment) and Provincial Electricity Authority (purchased electricity)

Executive summary

Thai Biogas Energy Company (TBEC), founded in 2003, is a one-stop shop for premium biogas Build Own Operate and Transfer (BOOT) projects with strong emphasis on high biogas yield, safety, quality of construction and quality of its human resources. It has implemented a number of biogas projects in Southeast Asia to treat effluents from agro-industrial units, such as palm oil and cassava processing plants. The biogas generated from treating wastewater is used to generate electricity, which is sold to the Thai electricity grid via a provincial electricity authority. Some projects have also received carbon credits for contributing to reductions in GHG emissions. These credits are purchased by companies in Europe. The treated wastewater also has useful mineral and nutrients for plants and is sometimes reused to irrigate rubber trees, or more typically released into public canals. Through its business model, TBEC's investment results in employment of local labor for biogas plant construction. TBEC also shares its revenue, technology and expertise with the host company and provides training to facilitate easy transfer of the project at the end of BOOT period. Since 2016, TBEC has been managed

by Asia Biogas Group. It has 8 power plants in Thailand and 1 in Lao PDR. TBEC projects produce 44 million m^3 of biogas or 88 GWh equivalent of biogas annually, and reduce greenhouse gas emissions by 320,000 tCO_2e per year.

TBEC is certified ISO 9001, ISO 14001, and follows the guidelines of the International Finance Corporation (IFC) of Thailand on global warming. TBEC is the market leader in the Mekong area for biogas projects for cassava wastewater in Rayong, Kalasin, Saraburi in Thailand, and for the palm oil and rubber industry in Surat Thani. The TBEC Tha Chang Biogas Project won many awards, including Best Biogas Project in Asia Selling Electricity to the Grid at the ASEAN Energy Award in 2010, the Crown Standard from the Thailand Greenhouse Gas Management Organization (TGO) and the designated national authority (DNA) of Thailand and Gold Standard by the World Wide Fund.

KEY PERFORMANCE INDICATORS (AS OF 2013)						
Land:	Land is provided by concessionaries/industry owners					
Water requirements:	Most is 'wastewater' output – 25,000 m^3 of treated wastewater/day					
Capital investment:	Highly project-specific depending on scale, location, labor and benefit sharing arrangements with concessionaires, but as an illustration installing a 1.4 MW biogas power plant involves investment costs of approximately 3.5–3.9 million USD in 2008					
Labor:	116 full-time employees (including O&M of multiple plants)					
Output:	25,000 m^3 of treated wastewater/day; Across several projects, TBEC has processed 6,200,000 m^3 of wastewater/year, converted 97,250,000 kg COD/year into around 38,360,000 Nm^3 of biogas/year, 26,500,000 kWh of electricity/year and 250,000 tCO_2e/year of CERs					
Potential social and/or environmental impact:	Reduced dependence on imported fossil fuels for power generation; CO_2 emission reduction; local jobs in construction of plant; skilled jobs in operation and maintenance; reduced nuisance odors and water pollution					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Recognizing the need to reduce GHG emissions to mitigate climate change, TBEC promotes use of cost-effective and environmental-friendly renewable energy such as biogas generated from agro-processing wastewater. TBEC have hired Waste Solutions Ltd, a New Zealand firm of technology developers and consulting engineers, to design the plants. TBEC adopts a BOOT model, bringing in investment to set up biogas plants that treat wastewater from agro-industry factories that provide land and inputs. TBEC finances, designs, constructs, operates and maintains the plant until BOOT term expires. TBEC recovers its costs by producing electricity and selling it to a provincial electricity authority. Training is provided to help the host company after transfer of project. The business has operated projects in Thailand and in Lao PDR and is developing ones in Myanmar, Cambodia and Vietnam. The TBEC has installed and is operating six projects at starch units and three projects at palm oil mills. Examples of plants installed and operated by TBEC include Rayong, starch plant (15,000 m^3/day biogas, 1.4 MW of power); Kalasin, starch plant (30,000 m^3/day, 2 MW); Saraburi, high fructose syrup from cassava (25,000 m^3/day and 1 MW in Lao) and Thachang project at palm oil mill and concentrated latex plant (35,000 m^3/day and 2.8 MW). The Thachang project has targeted CO_2 emission reduction of 51,823 tons/year. The construction of the Thachang project started in January 2007 and commissioned in November 2008. Operation started in January 2009, and registration with UNFCCC was in September 2010.

TBEC raised finance from the Private Energy Market Fund (PEMF) in Finland and Al Tayyar Energy (ATE) in Morocco for setting up these plants. PEMF is a private equity fund for alternative energy development and power conservation. It holds about 70% of TBEC. Al Tayyar Energy (ATE) is a clean power development and investment company founded by HRH Prince Moulay Hicham Ben Abdallah Al Alaoui of Morocco. It has head office in the UAE. The company primarily focuses on bio-energies, such as biofuels, biogas and biomass. It also invests in solar, wind and hydroelectric project companies.

Market environment

Thailand is the world's third largest producer of crude palm oil and has one of the largest tapioca processing industry. Most agricultural production processes have significant amounts of organic residue output as a by-product. There are also many underutilized agro-processing waste sources not only in Thailand but also around the region. Due to increasing pressure to reduce GHG emissions, such agro-processing units, the customers of TBEC are looking for ways of treating wastewater from such processing of agricultural products including palm oil or starch from cassava. The waste-to-biogas and power business of TBEC contributes to greater use of renewable energy, allowing the firm to make a profit by selling electricity at preferential prices, as well as carbon credits while improving the environment. The electricity generated is directly sold to the grid of the Provincial Electricity Authority (PEA). Electricity demand is expected to continue to grow over the coming decades despite significant efforts in improving efficiency. Electricity prices are regulated by the government to ensure electricity is priced at a rate which is accessible to both residential and industrial users.

With high quality and safety standards, TBEC is a premium product company with around 10 competitors. For instance, Asia Biogas Company Ltd, Prapob Company and several other newcomers. Most of the new enterprises contract for construction of biogas plants and do not invest and operate the plant. As of 2008, 21 CDM projects in the palm-oil sector were registered with the Thai Greenhouse Gas Management Organization (TGO). The number of approved CDM projects in Thailand is still limited due to the high level of burdensome bureaucratic procedures involved.

Macro environment

The fossil fuels account for 80% of the total energy supply in Thailand. The Government of Thailand targets to increase the share of alternative energy from 6.4% at present to 20.3% of commercial primary energy by 2022, as per the Renewable Energy Development Plan. To achieve the above targets, the Government of Thailand supports the projects by several incentives such as subsidization, soft loan, tax incentive, Board of Investment (BOI), Energy Service Company (ESCO) Fund, CDM, adder cost, etc.

Thailand, with its abundant and varieties of biomass and agricultural wastes, has the great challenge and opportunity for the waste-to-energy projects to supply renewable energy-based electricity. Thailand's Ministry of Energy estimates that the potential of power generation in Thailand from biomass, MSW and biogas is 3,700 MW. Bio-based renewable energy (RE), such as agricultural residues, crops, biogas from biomass and wastes, MSW and biofuels, has shared in a large portion of RE more than 90% of potential RE in Thailand. For example, with 64 palm-oil mills, Thailand had a potential of more than 5 million m^3 of biogas/year from palm oil mill effluent (POME) that can generate more than 50 GWh of electricity/year.

Business model

TBEC develops, designs, finances and operates biogas projects on a Build-Own-Operate-Transfer (BOOT) while the concessionaries provide land and inputs and operates the plant after expiry of BOOT period (Figure 100). The BOOT period is flexible and depends on type and characteristics of individual

FIGURE 100. TBEC BUSINESS MODEL CANVAS

KEY PARTNERS

- Wastewater producers
- PEMF, Finland
- Al Tayyar Energy, Morocco
- Provincial Electricity Authority

KEY ACTIVITIES

- BOOT biogas projects
- Selling the biogas to the boiler for drying process
- Selling renewable electricity
- Marketing carbon offsets
- Producing and selling fertilizer (future option)
- Training BOOT customers as part of quality services

KEY RESOURCES

- Wastewater
- Land
- Capital
- Skilled labor
- Experienced top management team
- Technology
- Government policies
- Longer-term agreements with suppliers
- Long-term power purchase agreement with the Electricity Authority

VALUE PROPOSITIONS

- Wastewater treatment for agro-industries through well-serviced BOOT model
- Renewable electricity supply to the Thailand state electricity
- Carbon offset generation
- Organic fertilizer (future option)

CUSTOMER RELATIONSHIPS

- Agreements with agro-industries
- Direct PPA with PEA
- Direct with carbon trading markets

CHANNELS

- Direct to biogas plant from the host company
- Connect to national grid
- Carbon trading markets

CUSTOMER SEGMENTS

- Agro-industry that process cassava, palm oil or ethanol
- Provincial electricity authority
- European institutions purchasing carbon offset
- Farmers (future option) needing fertilizer

COST STRUCTURE

- Infrastructure investment (high)
- O&M cost (high)
- Training

REVENUE STREAMS

- Sale biogas to the host company for drying process
- Sale of electricity to provincial electricity authority
- Sale of CO_2 offset through CDM
- Sale of fertilizer (future option)

SOCIAL & ENVIRONMENTAL COSTS	SOCIAL & ENVIRONMENTAL BENEFITS
▪ In case of leakage of gas, there are consequences to the environment	▪ Jobs creation ▪ Indirectly increase income to the farmers ▪ Reduce the odor of the wastewater ▪ Environmental benefit through reduced CO_2 emissions by generating electricity from renewable source and reducing pollution (fossil fuels substitution)

projects. It normally takes between 15 to 17 years before the transfer is made to the host company. Thus, key customers are the agro-industrial unit and the entity purchasing electricity which is the Provincial Electricity Authority (PEA) in Thailand. TBEC's unique selling point is quality of product and service, appealing to higher-value markets.

Value chain and position

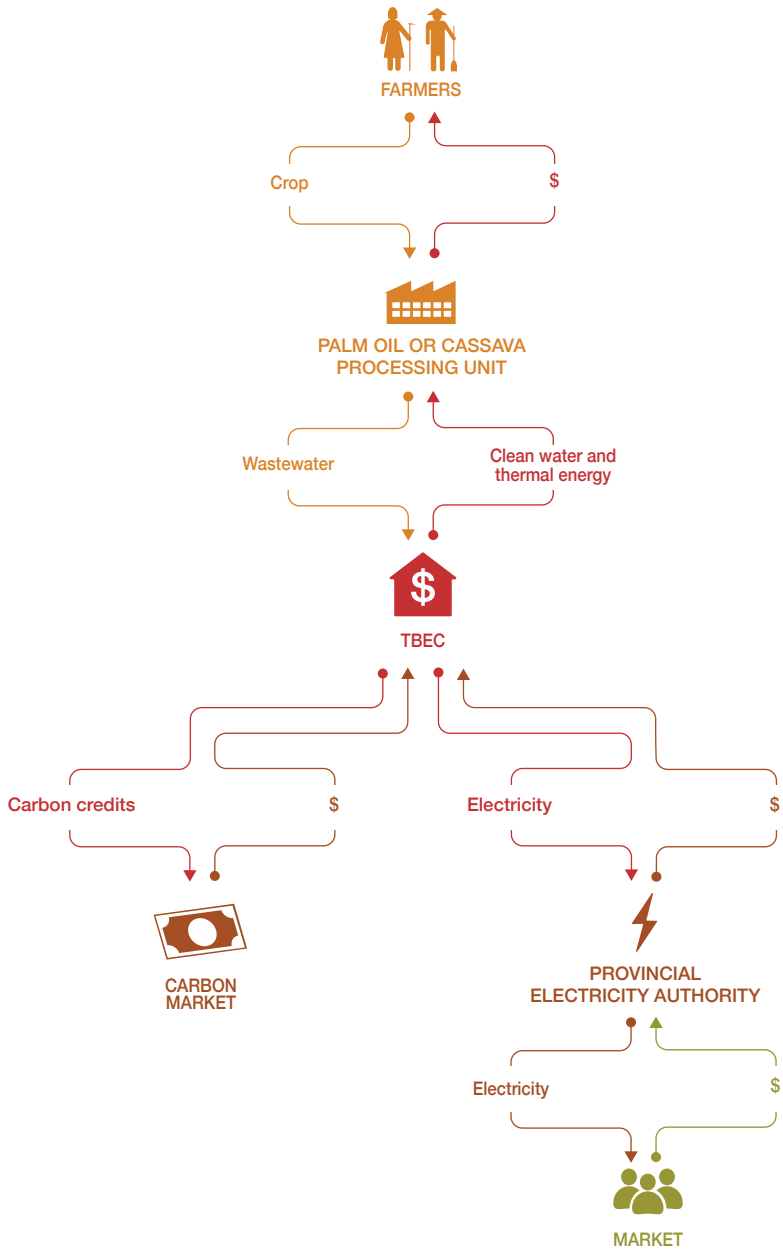
Figure 101 describes the relationship between some of the key value chain actors in a typical TBEC project. TBEC treats wastewater from agro-processing units (like palm oil) to generate electricity. The major supplier of the plant's raw material is the agro-industry with which TBEC has an agreement to treat waste from the process. Threat to supply of effluent does not exist due to such agreements. The biogas it generates from treating wastewater is used to produce electricity, which is sold to the Thai electricity grid. TBEC has a PPA with the electricity authority, and thus threat of buyer power is low. Electricity as well as thermal energy (heat) could also be sold back to host agro-processing units directly under energy purchase agreement. Carbon credits may be purchased by companies in Europe. The BOOT agreements cover sale of concessions to partners. Thus, the specific role of TBEC in a project can be substantial over time and has certain challenges. Biogas power plants are quite complicated and require careful supervision. Unprofessional management can reduce cost-effectiveness and increase risks. Seasonality of biogas production can cause trouble with production planning.

TBEC develops a project under CDM to obtain CERs and successfully completed United Nations Framework Convention on Climate Change (UNFCCC) registration of all its projects as CDM projects. For example, the actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved during the period of January 1, 2013 to December 31, 2014 were 91,678 tCO_2e against the estimated amount of 51,823 tCO_2e for Thachang project. The examples of the biogas yield from different dry substrates are as follow: 200–400 m^3/ton of cattle manure and dung, 250–450 m^3/ton of pig and chicken dung, 350–700 m^3/ton of energy crops and 700–900 m^3/ton of POME (FNR, 2007 and 2009). A value-added option is to turn the biogas into green gas by removing CO_2 and other gaseous components (H_2S, H_2O) content and increasing the percentage of methane. Compared to the biogas, the green gas and natural gas contain 29% more methane.

Institutional environment

Thailand is one of the first countries in Asia to have a policy to encourage biofuels, cogeneration, distributed generation and the generation of power from renewable energy. Co-generation and the production of power from renewable energy is implemented under the Small Power Producer Program (SPP) of 10–90 MW capacity and Very Small Power Producer Program (VSPP) of less than 10 MW capacity. It became a very effective policy instrument in promoting investment in renewable energy and co-generation. Private power producers sell electricity to the electric utilities under power purchase agreements at a price determined based on avoided cost or users located nearby. The VSPP has a more

FIGURE 101. TBEC VALUE CHAIN



lenient set of requirements and less complicated power purchase arrangement of 'net metering'. The SPP and VSPP regulations have been amended to be more investor-friendly and practical, including changes to the criteria for qualifying facility, calculation of the avoided cost and interconnection requirements. In addition, the government also launched a program to encourage the renewable energy SPPs by providing an additional tariff for a period of 5–10 years from the Energy Conservation

Fund. The "adder" was determined through a competitive bidding system, which resulted in approval of 14 projects with average "adder" of 0.18 baht per kWh (US¢ 0.56), representing approximately 5% increase from the normal tariff. Financial incentives through soft loans and investment subsidies were expanded in amount and coverage for selected types of renewable energy projects, in particular biogas in pig farms and factories producing tapioca starch, palm oil, rubber sheet, ethanol and other types of agro-industry, municipal wastes and micro hydro. This has given an enormous boost to a number of marginal projects, particularly biogas and municipal waste projects.

The PEA is a government enterprise with prime responsibility concerned with the generation, distribution, sales and provision of electric energy services to the business and industrial sectors, as well as to the general public in provincial areas, with the exception of Bangkok, Nonthaburi and Samut Prakran provinces. The PEA has expanded electricity supply to all areas covering 73 provinces, approximately 510,000 km^2, accounting for 99% of the country's total area.

Technology and processes

TBEC applies a robust, flexible and highly productive Covered Lagoon Bio-Reactor (CLBR) technology suitable for changing volumes and quality of wastewater discharged from industrial factories. Wastewater passes through an anaerobic digestion process through which organic substances such as proteins, carbohydrates and fats are digested by bacteria in a suitable environment and are finally transformed into biogas. The CLBR has uniquely designed mixers, baffles and a thick high-density polyethylene (HDPE) cover with optimized contact with anaerobic bacteria to convert organic matter into biogas. Temperature is a key factor in planning a covered lagoon. Warm climates require smaller lagoons and have less variation in seasonal gas production. Cover materials must be: ultraviolet resistant; hydrophobic; tear and puncture resistant; non-toxic to bacteria and have a bulk density near that of water. The recovered biogas can be used to produce space heat, hot water, cooling or electricity. The biogas is collected in pipes, cleaned and stripped of condensate, dust and hydrogen sulphide and compressed and fed to dedicated biogas engines if used for power generation. The GE Jenbacher engine is designed specifically for gas applications and is characterized by particularly high efficiency, low emissions, durability and high reliability. The engine is designed with a knock control system which increases reliability and availability through control of firing point, output and mixture temperature. The engines gas mixer has been optimized to meet the requirements of modern gas engines and ensure trouble-free operation with biogas. In case of any excess build-up of biogas, the surplus gas will be combusted or flared. The effluent released from the digester is either recycled or sent to a small settling pond where sediment is settled and returned to the digester. The treated waste leaving the treatment system boundary is then pumped to existing water treatment lagoons.

A typical 200 tons-per-day starch factory can produce as much as 25,000 m^3 of methane (4.5 MW) from the cassava wastewater and 16,000 m^3 of methane (2.8 MW) from the cassava pulp. This is equivalent to 40,000 L of heavy fuel oil (HFO) per day or can be used to produce up to 7.3 MW of electricity per hour. Some of the areas of focus for new development are reactor configuration, process control, modelling and optimization for improving biogas yield; use of other feedstock such as solid residual, and energy crops; pre- and post-treatment for digestibility improvement and nutrient recovery; improved biogas clean up processes and upgrading biogas to high value/rich methane gas for fuel cell, vehicle, CNG, etc.

Funding and financial outlook

The investment costs covering project development, design, construction and start-up system depend on the size, location and duration of contract for individual projects. The major investment costs are plant machinery/equipment with minor cost of building and small cost of engineering services

and other infrastructure. It should be noted that land and material costs are covered by concession partners. Historically, a key constraint has been reluctance of Thai domestic financial institutions to finance waste-to-energy products. Most financial institutions still define waste-to-energy business as a high-risk business. Unfamiliarity and trust that carbon credits can be saleable to European countries is part of the explanation. For that reason, partners invested their own money in order to initiate the business in 2003. At present, some Thai financial institutions offer refinance since they now realize the business potential.

The main revenue streams are from the sale of biogas and electricity and construction and maintenance under BOT schemes. Carbon credits are still relatively modest. Overall conditions that effect revenue streams include government policies, seasonality and prices. Seasonality is important as unusual seasons or weather conditions have an impact on inputs to the commodity processing factories that, in turn, produce wastes that are turned into energy. Table 28 shows the indicative cost structure of operations expressed in terms of approximate percentage of annual investment cost.

TABLE 28. OPERATIONAL AND MAINTENANCE COSTS OF TBEC

COST ITEM	OPERATIONS COSTS AS A % OF INVESTMENT COST
Equipment (depreciation)	*Approx. 65%*
Labor	*Approx. 10%*
Maintenance	*Approx. 15%*
Electricity	*Approx. 5%*
Building	*Approx. 5%*

The financial parameters of the typical project (based on Thachang project) are as follows:

1)	Capacity of plant	2.8 MW
2)	Term of BOOT contract	10 years
3)	Investment cost	USD 3.9 million
4)	O&M cost	USD 0.2 million
5)	Electricity sold to grid per year	9,644 MWh
6)	Average tariff per kWh	USD 0.076
7)	Escalation in O&M cost per year	2%
8)	Increase in tariff per year	2%
9)	Average CERs per year	48,694 tons
10)	IRR (without CERs)	4.44%
11)	IRR (with CERs)	20.60%

Socio-economic, health and environmental impact

The project will create an indigenous renewable electricity resource, replacing power from coal, diesel and natural gas, and will contribute to the development of the region, as well as national economy by reducing Thailand's deficiency of power and need to import fossil fuels. In terms of environmental benefits, the project reduces existing levels of pollutants in wastewater; air pollution; GHG with positive impact on the health of those living around the plant and mitigates global warming by trapping methane. TBEC hires local labor for the construction and operation of biogas plant. The project will directly create more than 10 new jobs, and thus increase stakeholder incomes. It will improve human capacity and diversity of employment opportunity by training project managers, lab technicians and operators.

Scalability and replicability considerations

Key drivers to the success of this business are:

- Strong partnership among different institutions – technology developer, agro-processing businesses and electricity authority and financing institutions.
- Ability to raise finance to set up effective BOOT schemes for various agro-industries.
- Expertise in biogas plant operation.
- The government policy and interest in promoting renewable energy based power.

TBEC already has experience in taking its technology and business model from core operations in Thailand into Lao PDR. TBEC is also in talks with agricultural enterprises in Vietnam and Indonesia to produce biogas from cassava. A bank overseas has already lent EUR 10 million (THB 416 billion) for new projects. They have replicated the model with multiple agro-industries. As the technology can process any organic matter, the business model has potential to reach out to municipalities to process the organic component in the MSW as well.

Summary assessment – SWOT analysis

The key strengths of the business are setting up of effective BOOT schemes, expertise in biogas plant operation and strong partnership with agro-industry (Figure 102). TBEC is branded as a premium

FIGURE 102. SWOT ANALYSIS OF TBEC

	HELPFUL TO ACHIEVING THE OBJECTIVES	HARMFUL TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Assured supply of wastewater due to secured rights ▪ Effective BOOT scheme ▪ Strong partnership with agro-industry ▪ Expertise in biogas plant operation ▪ Securing of long-term power purchase agreement ▪ Highly robust technology	**WEAKNESSES** ▪ Complex biological processes ▪ High cost of technology ▪ Requirement of high skilled labor makes recruitment of staff difficult ▪ No immediate market for treated water ▪ Time taken for agreement and partnerships for every new project
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Environmental stress reduction offers environmental credit market opportunities ▪ Treated wastewater has potential for fertilizer due to the process ▪ Expansion potential to other agro-processing plants such as sugar, ethanol and liquor production due to highly robust technology ▪ Electricity demand is growing and need for renewable-energy-based electricity generation increasing in Thailand ▪ Good potential of foreign investment if the incentive policy is retained	**THREATS** ▪ Possible human health risk may lead to investment needs ▪ Possible risk from leakage of gas, thus having negative perception of health risk to employees may force O&M cost up ▪ Seasonality regards biogas production ▪ Volatility of international carbon market

product-service company as it puts more emphasis on quality and safety. However, the technology is high-priced and requires highly-skilled labor. There is no market yet for treated wastewater, but there is an opportunity to use the treated wastewater for agriculture. Growing electricity demand and application of the technology to other agro-processing plants such as sugar, ethanol and liquor production present opportunities for TBEC to expand.

Acknowledgements

Sincere thanks to Pajon Sriboonruang, Chief Operating Officer of the Thai Biogas Energy Co Ltd for agreeing to be interviewed and for providing documents about the company, Chatta Duangsuwan for helping with the interview and site visit and Kalayanee Surapolbhichet for assisting with liaison with TBEC and translation.

Contributors

Nikiema Josiane, IWMI, Ghana
Thai Biogas Energy Company
Johannes Heeb, CEWAS, Switzerland
Jasper Buijs, Sustainnovate; Formerly IWMI
Kamalesh Doshi, Simplify Energy Solutions LLC, Ashburn, Virginia, USA

References and further readings

Chaiprasert, P., Biogas production from agricultural wastes in Thailand. Journal of Sustainable Energy and Environment (2011): 63–65.

FNR. 2007. Fachagentur Nachwachsende Rohstoffe e.V. Renewable resource in industry, 2nd ed. www.fnr.de.

FNR. 2009. Fachagentur Nachwachsende Rohstoffe e.V. Biogas: An introduction, 2nd ed. www.fnr.de.

Foran, T., du Pont, P., Parinya, P. and Phumaraphand, N. Securing energy efficiency as a high priority: Scenarios for common appliance electricity consumption in Thailand. Energy Efficiency 3, no. 4 (2010): 347–364.

Pattanapongchai, A. and Limmeechokchai, B. Least cost energy planning in Thailand: A case of biogas upgrading in palm oil industry. Songklanakarin J Sci Technol 33, no. 6 (2011): 705–715.

Tantrakarnapa, K., Utachkul, U., Aroonsrimorakot, S. and Arunlertaree, C. The potential of greenhouse gas reduction from clean development mechanism implementation in cassava starch and palm oil industries in Thailand. Journal of Public Health (2008): 130–139.

Thai Biogas Energy Co Ltd. About us. www.tbec.co.th/e_about_us.php (accessed August 18, 2017).

Thai Biogas Energy Co Ltd. Our projects. www.tbec.co.th/e_our_project.php (accessed August 18, 2017).

Watcharejyothin, M. and Shrestha, R. Regional energy resource development and energy security under CO_2 emission constraint in the greater Mekong sub-region countries (GMS). Energy Policy 37(2009): 4428–4441.

Watcharejyothin, M. and Shrestha, R. Effects of cross-border power trade between Laos and Thailand: Energy security and environmental implications. Energy Policy 37(2009): 1782–1792.

Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2015/2016). As business operations are dynamic, data can be subject to change.