Minimizing Greenhouse Gas Emission through Integrated Waste Management: Case Studies in Thailand

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Abstract

Global warming is a serious environmental problem worldwide. Thailand has been affected by global warming through severe flooding and drought, resulting in negative impact on health and development. Efforts to minimize greenhouse gas (GHGs) emission have been undertaken by several sectors, especially those involved with energy utilization and environmental control. This study evaluated the performance of a Waste-To-Energy (WTE) project located in northeast Thailand which, through a Clean Development Mechanism (CDM), treats about 7,000 m^3 per day of tapioca processing wastewater with an Anaerobic Baffled Reactor (ABR). The ABR could reduce chemical oxygen demand of tapioca processing wastewater by more than 90% and the methane gas generated of 50,000 - 80,000 m^3 per day was used to replace approximately eight million litres per year of heavy fuel oil required to supply about 20,000 MWh per year of electricity into the grid. In addition, the WTE project results in certified emission reductions (CERs) of 300,000 tonnes CO_2 equivalent per year. At the 2008 CERs rate of Euro10 per tonne CO_2 equivalent, this would bring in additional income of 3,000,000 Euro or about 120 million baht per year. Another study evaluated the performance of the other WTE facility of the Rayong municipality, eastern Thailand, where about 20 tonnes of municipal solid wastes per day are treated by anaerobic digestion. The methane gas produced from this treatment is fed to a co-generator to produce about 3,360

MWh of electricity per year. From an environmental perspective, this WTE facility was able to reduce GHGs emission of 7,150 tonnes CO_2 equivalent per year. The above case studies demonstrated the effectiveness of WTE facilities in minimizing GHGs emission and their performances were found to be environmentally, economically and socially sustainable.

Key words: Global warming, Greenhouse gases (GHGs), Clean Development Mechanism (CDM), Waste-To-Energy (WTE)

Abbreviations

ABR	Anaerobic Baffled Reactor
AD	Anaerobic Digestion
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
COD	Chemical Oxygen Demand
EPPO	Energy Policy and Planning Office, Thailand
GHGs	Greenhouse Gases
HRT	Hydraulic Retention Time
IOC	Item for Objective Congruence
IPCC	Intergovernmental Panel on Climate Change
KWTE	Korat-Waste-To-Energy
MSW	Municipal Solid Wastes
ONEP	Office of Natural Resources and Environmental Policy and Planning, Thailand
SWI	Sanguan Wongse Industries
SD	Sustainable Development
TGO	Thailand Greenhouse Gas Management Organization (Public Organization)
UNFCCC	United Nations Framework Convention on Climate Change
VS	Volatile Solids
WTE	Waste-To-Energy

1. Introduction

The global climate change problems caused by greenhouse gases have been recognized worldwide. Climate change is the result of human activities, particularly from burning fossil fuels and deforestation, leading to higher CO_2 concentrations in the atmosphere, which absorb heat and radiation from the Earth's surface and consequently lead to global warming. Increased temperatures are the major cause of extreme seasonal changes, polar glaciers melting and sea levels rising, all of which have negative impacts on social, environmental, and economic development at both national and international levels. This is the reason why climate change issues should be of immediate concern and must be addressed at all levels in order to mitigate and adapt to any changes that might occur.

Clean Development Mechanism (CDM) is an alternative mechanism established by the Kyoto protocol in 1997 as a key instrument to assist developed or Annex 1 countries to reduce GHGs emission, namely CO_2, methane (CH_4), nitrous oxide, hydro fluorocarbons, per-fluorocarbons, and sulfur hexafluoride. The resulting certified emission reductions, known as CERs (Fig. 1), can be used by Annex I countries to help meet their emission reduction targets (total cut in GHGs emissions consists of 5% from 1990 levels in the first commitment period of 2008-2012). This should lead to sustainable development in the host countries and measurable, long-term benefits in terms of climate change mitigation.

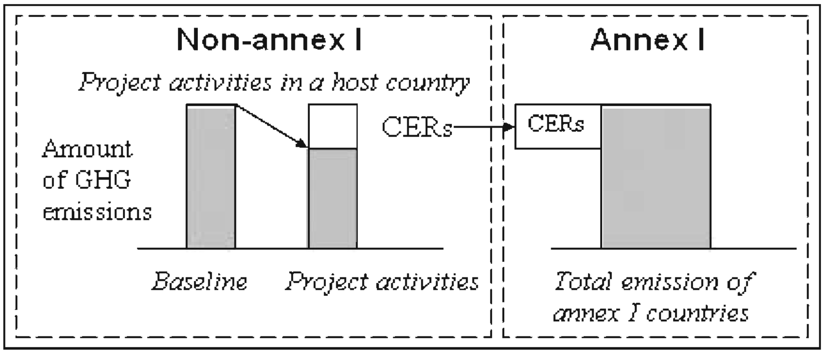

Figure 1 Implementation of CERs for GHGs emissions reduction of Annex 1 countries(IGES, 2006)

The 7th National Economics and Social Development Plan of Thailand promotes the production of electricity from renewable sources such as biomass, solar, wind, and municipal solid wastes (Hirunlabh, 1997). Because the composition of wastes in Thailand is mainly organic (~40%), there is a high potential to produce biogas from these wastes and convert it into heat and electricity, hence reducing fossil oil consumption and consequently minimizing GHGs emission.

The overall objective of this study was to evaluate the performance of the integrated waste management or WTE projects for minimizing GHGs emission from agro-industrial wastewater and municipal solid wastes which are the major types of organic wastes in Thailand and to assess their sustainability with respect to the environmental, economic and social aspects.

2. Materials and Methods

Data presented in this article was obtained from the WTE projects at the Sanguan Wongse Industries (SWI) factory in Nakhon Ratchasima, northeastern Thailand, where starch products are produced (KWTE, 2005), and from the WTE project of the Rayong municipality, Thailand, where organic solid wastes are treated by anaerobic digestion (RMO, 2006). The environmental and economic aspects of these WTE projects were evaluated based on biogas and electricity production. Additional data, including that relating to the social aspect, was obtained from field surveys, sampling and analysis, as well as questionnaires and interviews with the stakeholders concerned.

The validity of the questionnaires was estimated through the Item for Objective Congruence (IOC) method (Hambleton, 1978) based on experts' views. The questionnaires' reliability was estimated via Cronbach's alpha coefficient (Cronbach, 1970) by measuring the internal consistency of questionnaires. The determination of sampling size of the participants or target group was based on statistical analysis. Likewise propagation and development of the lessons learned from the WTE projects for integrated waste management to minimize GHGs emissions were developed from this study.

3. Results and Discussion

3.1 CDM projects implementation in Thailand

According to the Thailand Greenhouse Gas Management (Public Organization) (TGO, 2008), fourteen CDM projects have been approved by the Thai cabinet (seven from biomass, six from biogas and one from landfill, Table 1). TGO has been recently established to expedite the implementation of CDM projects by promoting foreign investment and technology transfers from Annex I countries and the development of sustainable GHGs reduction projects in host countries. Up to the present, the TGO has endorsed 39 CDM projects which need to be further approved by the Thai cabinet (TGO, 2009).

Table 1 CDM projects in Thailand (TGO, 2008)

CDM projects	GHGs reduction (tonnes CO_2/yr)
Biomass projects	
Dan Chang Bio-Energy Cogeneration Project, Suphanburi	93,130
Phu Khieo Bio Energy Cogeneration Project, Chaiyaphum Province	102,490
A.T. Biopower Rice Husk Power Project, Pichit Province	77,290
Rubber Wood Residue Power Plant, Yala Province	60,000
Khon Kaen Sugar Power Plant, Khon Kaen Province	61,450
Surat Thani Biomass Power Generation Project, Surat Thani Province	173,360
Surin Electricity Company Limited, Surin Province	12,200
Biogas projects	
Korat Waste to Energy Project, Nakorn Ratchasima Province	312,770
Wastewater Treatment with Biogas System in a Starch Plant for Energy and Environment Conservation, Nakhon Ratchasima Province	31,450
Wastewater Treatment with Biogas System in a Starch Plant for Energy and Environment Conservation, Chachoengsao Province	19,370
Natural Palm Oil Company Limited-1MW Electricity Generation and Biogas Plant Project, Surat Thani Province	17,530
Northeastern Starch (1987) CO., Ltd - LPG Fuel Switching Project, Nakhon Ratchasima Province	27,320
Chumporn Applied Biogas Technology for Advanced Waste Water Management, Chumphon Province	23,440
Landfill gas project	
Jaroensompong Cooperation Rachathewa Landfill Gas to Energy Project , Samut Prakan Province	47,190

3.2 CDM project for GHGs reduction at a starch-processing factory

This case study was conducted at the SWI factory, which processes 2,400 tonnes of raw cassava roots daily, and produces 550 tonnes of native starch products. The factory produces 7,000 m^3 of wastewater per day with chemical oxygen demand (COD) and suspended solid concentrations of 25,000 and 15,000 mg/l, respectively. This wastewater is treated by the ABR reactor (100,000 m^3 in size), which is operated at the hydraulic retention time (HRT) of 12 days. The biogas produced is converted to heat for use in cassava processing and electricity production as shown in Fig. 2. The ABR was able to remove 90% of the input COD, resulting in biogas production of 90,000 - 130,000 m^3per day or 50,000 - 80,000 m^3 per day of CH_4.

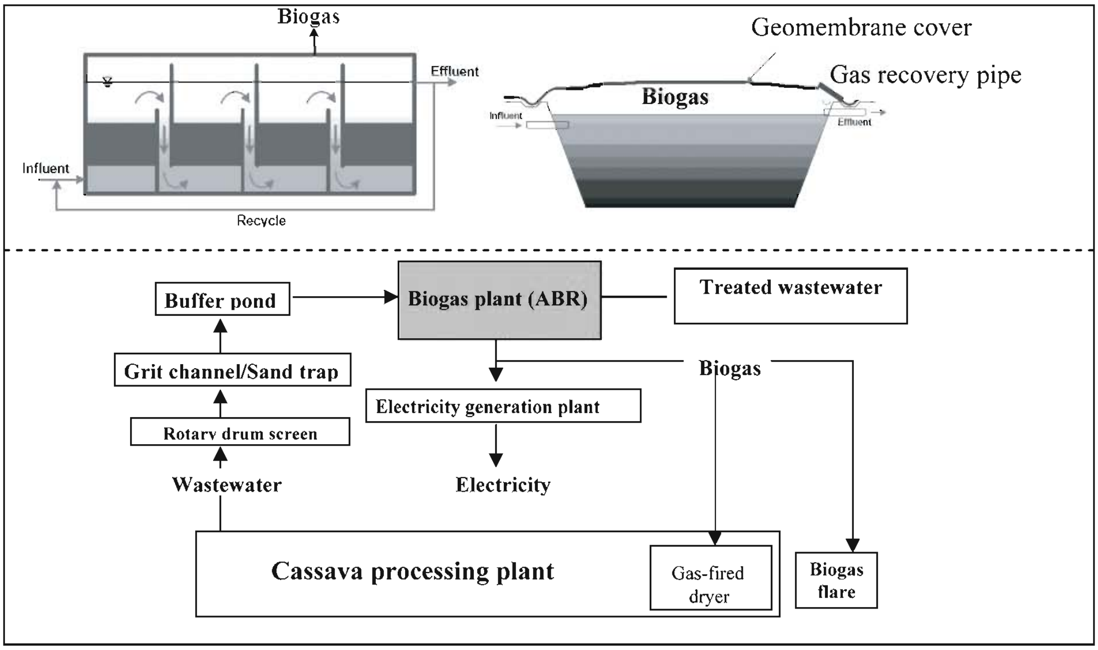

Figure 2 ABR system of the SWI factory (KWTE, 2005).

The CH_4 gas produced from the ABR system is used to replace approximately eight million litres of heavy fuel oil per year consumed in the production of about 20,000 MWh per year of electricity for the grid. This CH_4 utilization results in mitigation of GHGs emission of 300,000 tonnes CO_2 equivalent per year which, based on the CDM and CERs rate of Euro 10 per tonne CO_2 equivalent, would yield an additional income of Euro 3,000,000 (or 120 million baht).

Sustainability assessment of the CDM project at the SWI factory was conducted by Kittipongvises (2008) and was based on the economic, environmental and social aspects using the sustainable development (SD) criteria of the Office of Natural Resources and Environmental Policy and Planning (ONEP). The questionnaires were sent to about 260 stakeholders who were involved in this project or lived nearby the factory area. According to ONEP (2007), the SD scores were assigned at 1 (negative impact), 2 (no impact), 3 (positive impact) and 4 (positive impact with outstanding benefits to the community). The results obtained from the questionnaires were tabulated and compared with those previously obtained by ONEP (2007), as shown in Fig. 3. The validity of the questionnaires estimated through the IOC method was 0.83, higher than 0.5, meaning that the questionnaires had adequate validity for the data collection. The reliability of the questionnaires estimated through Cronbach's alpha coefficient was 0.76, higher than 0.7, meaning that the questionnaires had adequate reliability for the study.

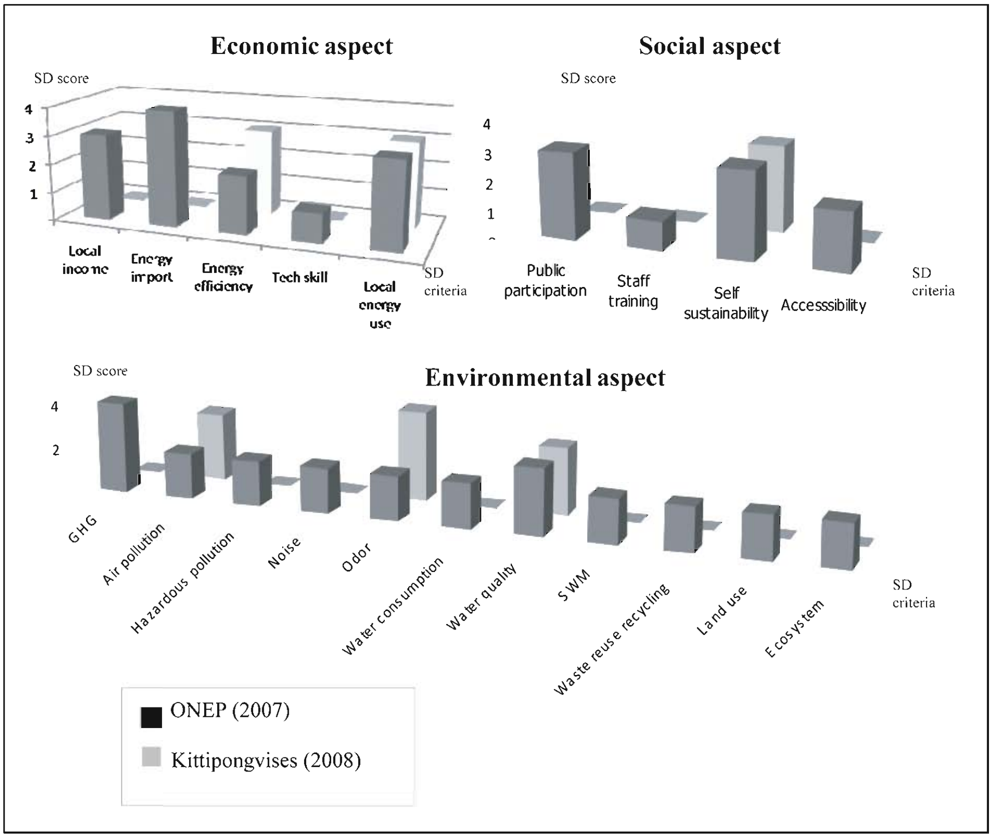

Figure 3 Overall results of questionnaires survey compared with ONEP evaluation of sustainability of the CDM project of the SWI factory.

An earlier sustainability assessment done by ONEP (2007) was based on the views of experts, who found the CDM project of the SWI factory to be sustainable and that the SD scores were mostly above 2 with an average value of 2.33 (Fig.3). The stakeholders interviewed by Kittipongvises (2008) were mostly local communities who were not very aware of GHGs and global warming issues, and responded to these issues in the questionnaires by giving SD scores of 1 or 2. However, these stakeholders could clearly understand environmental and energy issues and, consequently, gave higher SD scores on "air pollution", "odour", "water quality", and "energy" (Fig. 3). Overall, based on the SD scores of ONEP (2007) and Kittipongvises (2008), this kind of CDM project appears to be positive and sustainable and should be implemented at other agro-industrial factories to minimize GHGs emission and promote sustainable development in Thailand. A lesson learned from this study suggested that more efforts should be made to involve local stakeholders in project planning and implementation and to raise their awareness about emerging issues relating to energy and the environment (Kittipongvises, 2008).

3.3 WTE project of the Rayong municipality, Thailand.

The Rayong municipality produces about 70 tonnes per day of solid wastes of which about 40% are organic and food wastes. Due to good initiatives and cooperation of the local people, the food wastes are separated and collected for treatment by anaerobic digestion (AD) to produce biogas for electricity generation. Fig. 4 shows the flow diagram of the solid waste treatment, which includes the AD reactor, co-generator for electricity generation, and facility for compost fertilizer production from the digestate (RMO, 2002). The size of the AD reactor was 2,100 m^3 and the HRT was operated between 30 to 60 days (Jutidamrongphan, 2008).

Jutidamrongphan (2008) reported the amount of separated organic wastes fed to the AD reactor to be about 20 tonnes per day and the biogas production was 1,620 m^3 per day or 890 m^3 per day of methane. The electricity generated from the biogas was 3,360 MWh per year in 2007 and was sold to the Provincial Electricity Authority (PEA) of Thailand, earning about 6,700,000 baht per year. From an environmental perspective, the WTE facility was able to reduce GHGs emission about 7,150 tonnes CO_2 equivalent per year. The AD could reduce 50% of the input COD and about 70% of volatile solids, and the digestate production of six tonnes per day could be converted to compost fertilizers for agricultural application. Financial analysis of this WTE facility suggested this project to be attractive with a profit which could pay back the investment in 10.2 years.

Questionnaire survey and interviews with about 500 people in 24 communities near the WTE facility found most of these people to be concerned about global warming effects and were familiar with the WTE and its benefits in reducing GHG emission and generating electricity. Some of the problems related to this WTE project included: solid waste separation in which inappropriate types of plastic bags were used for the storage of food wastes, and lack of skilled manpower to operate the WTE facilities. There is still no regulation or policy on solid wastes separation and recycling in the Rayong municipality and in Thailand. This makes solid waste management and WTE operation less effective.

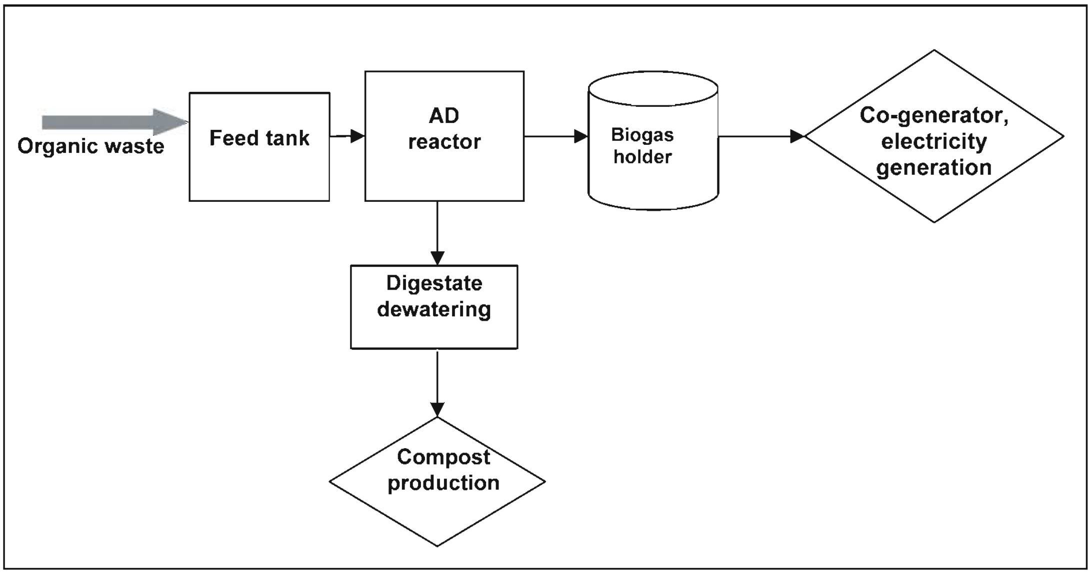

Figure 4 AD system flow process

4. Summary and Conclusions

To mitigate global warming problems, efforts to reduce GHGs emission should be done by all sectors. Thailand is an agricultural country located in the tropics and has a high economic growth rate, especially in the food production sector. For effective waste management, the application of the AD process to stabilize organic wastes, producing methane gas for use in electricity and heat generation, is an attractive approach. Besides its cost-effectiveness the AD system promotes the reduction of fossil fuel utilization and minimization of GHGs emission to the atmosphere. The major conclusions derived from this study are as follows:

(1) There are fourteen CDM projects approved by the Thai cabinet: seven from biomass, six from biogas and one from landfill. Another 39 CDM projects have been endorsed by TGO and to be approved by the Thai cabinet.

(2) The WTE at the SWI factory which employed the ABR process could remove more than 90% of the input COD from the tapioca processing wastewater, resulting in water pollution control, in addition to the benefit in minimizing GHGs emission.

(3) The WTE project at the SWI factory produced 50,000-80,000 m^3 of methane per day, electricity of 20,000 MWh per year and reduced GHGs emission of 300,000 tCO_2 equivalent per year. The project could bring an additional income of 120 million baht per year from carbon credit trading.

(4) The WTE project at the Rayong municipality which employed the AD reactor could reduce 50% of input COD and 70% of input volatile solids, hence contributing to pollution control and environmental improvement.

(5) The WTE project at the Rayong municipality produced 890 m^3 of methane per day, 3,360 MWh of electricity per year and reduced GHGs emission of 7,150 tonnes CO_2 equivalent per year, with a profit which could pay back the investment in 10.2 years.

(6) The above WTE projects were found to be economically, socially and environmentally feasible and the sustainability assessment was satisfactory.

(7) Lessons learned from these 2 case studies are:

• The local inhabitants should be engaged in the planning and operation of the WTE projects.

• Knowledge and awareness of emerging environmental issues, such as GHGs emission and global warming should be properly informed to the stakeholders and local communities concerned.

• There should be policy and regulation on solid wastes separation; and there should be skilled manpower to operate and maintain the WTE facilities.

5. Acknowledgements

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