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Comparative cost analysis of waste recycling for best energy alternative

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Abstract

The main purpose of this study is to demonstrate that the conversion of solid/green waste into renewable energy is not only environmentally beneficial, but also financially rewarding. Such advantages are validated by exploring the energy potential from market waste management and conducting a benefit-cost analysis (BCA) under two scenarios. The compost and biogas potentials are estimated through a simple analysis and a best suitable option for the green market of Thailand is suggested. The study area is, Talaad Thai, the largest agriculture market of Thailand. Furthermore, a benefit-cost analysis is conducted to propose a best suitable solution for managing organic waste in the market. The overall results show that biogas is the best suitable option for the green market and is not only environmentally sustainable, but financially sound as well. The policy makers of the market should ponder low cost and profitable policies in order to manage solid waste on a sustainable basis.

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Introduction

Thailand is one of the emerging economies of Southeast Asia with a population of 65 million, according to World Development Indicators, 2011. The complex interrelationship between environment and trade has become a focal point for international as well as national policy makers. Talaad Thai, Thailand's largest integrated agricultural wholesale market, located in Klong Luang district of Pathumthani province, was established in 1995 and managed by Thai Agro Exchange Company (TAECO) Ltd. It is spread across approximately 500 rai (200 acres) and is the distribution center for many domestic and international agricultural products, especially fruits and vegetables. The market facilities offer proper and quality infrastructure 24 hours a day, including security, 6 lanes of 30 meter main road, concrete parking areas, 3 modern style food centers, and a number of seven elevens, banks and shopping places for goods other than fruits and vegetables. Talaad Thai is managed and run by Thai Agro Exchange Company Ltd., an entirely private company that keeps their structural setup, planning, and procedures highly confidential to avoid competition, considering this the key to their successful position at the top of their sector in Thailand (Ali *et al.*, 2012; Ali *et al.*, 2010). Additionally, there is a Perishable One Stop Service Export Center (POSSEC) in Talaad Thai which provides quick services for the export of fruits, vegetables and flowers. This center is entrusted by the government which plays a role as co-operator under the supervision of the Department of Internal Trade, Ministry of Commerce, Thailand (Thechathanasombut, 2009).

In the Thai language, Talaad means market and Thai means of Thailand, so Talaad Thai literally means market of Thailand (Muttamara *et al.*, 2004). According to the solid waste management department of Talaad Thai, every day the market produces approximately 120 tonnes of solid waste, organic waste constituting almost 80% of that amount (Angkanawatana, 2009). This waste must be disposed of daily, otherwise it can become a significant problem, especially during rainy season. Thus a large amount of valuable waste is being treated as mere junk, while converting this waste into energy could result in a myriad of benefits. Talaad Thai does not have its own landfill or any nearby landfill to dispose such a huge quantity of solid waste, leading to the direct disposal of most waste. In particular, organic waste, which does not need to be disposed, is disposed of directly without any deliberation to recycle or reuse it. This organic waste, also called as green waste, thus creates an imbalance between the demand and supply sides of the waste management scheme (Abduli, 1995).

Studies around the world, and particularly in Asia (Adeoye *et al.*, 2011; Charuvichaipong and Sajor, 2006; Gandure *et al.,* 2013; Ihejirika *et al.*, 2011; Jabbour *et al.*, 2012; Krupa, 2012a; Krupa, 2012b; Lino *et al.*, 2012; Liu *et al.*, 2012; Mongkolnchaiarunya, 2005; Munnji *et al.*, 2013; Nagle *et al.,* 2011; Ndebele-Murisa *et al.*, 2013; Nigussie and Kissi, 2011; Ofori and Attuquayefio, 2012; Pathak, 2012; Seipt *et al.*, 2013; Udomsiri *et al.,* 2011; Xue, 2012) have focused on energy production from MSW obtained from cities like Thailand and counties at different levels. Other studies (Bouallagui *et al.*, 2005; Chaya and Gheewala, 2007; Foo and Hameed, 2010; Gorton *et al.*, 2011; Midmore and Jansen, 2003) have focused on the aerobic digestion of wastes from different sources, and still others have considered the industrial sector for the conversion of waste into energy solutions. However, none of these studies have taken into account the use of green market wastes to regenerate energy and/or biogas. Despite their fragile nature, products from green markets are less perishable and have immense potential for energy production, especially biogas.

Therefore, this study aims to investigate into the best suitable option for green waste management in Talaad Thai by comparing two recyclable opportunities, i.e. biogas and compost. The suitability of options is demonstrated through simple benefit-cost analysis which shows that conversion of waste into energy is bountiful, not only in terms of the environment, but with respect to finance as well.

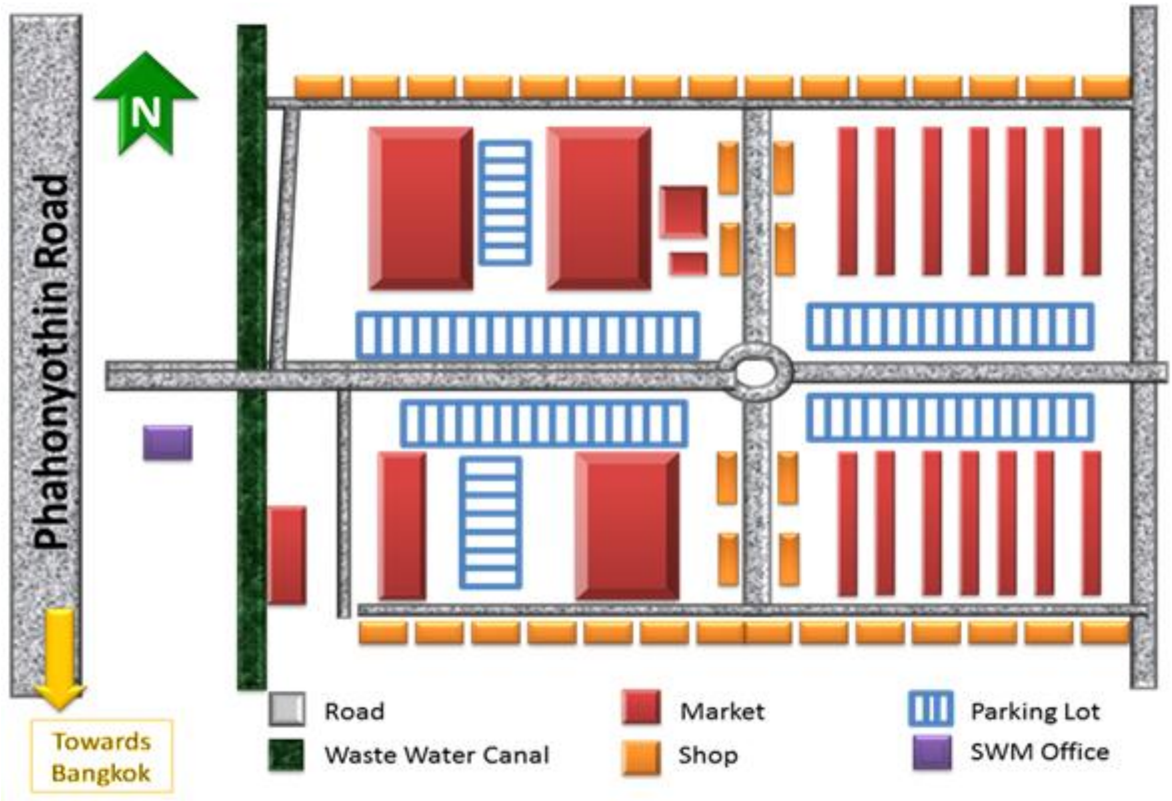

Fig. 1. An ariel view of study area (Talaad Thai).

Materials and methodos

This study is mixed approach using quantitative and qualitative methods. To achieve the ultimate goal, both primary and secondary data were collected. To conduct this research study, the study area selected was Talaad Thai. The overall scenario description is divided into two sets: one before the proposed situation and second with the proposed situation. A simple benefit-cost analysis (BCA) is performed to evaluate the ground truth situation. This is a common method widely used in different studies (Ali *et al.*, 2012; Fomby and Rangaprasad, 2007; Kothari *et al.*, 2010; Lavee, 2010; Pan *et a*l., 2012; Poullikkas, 2012; Rapport *et al.*, 2008; Shively and Galopin, 2002) for different purposes, but its application is very rare in biogas and compost related studies.

Benefit-cost analysis for solid waste management in Talaad Thai is calculated through two methods, in order to make clear distinctions between before and after situations. We discuss both the existing and proposed situations. The commonly used benefit–cost analysis has been performed several times in different studies, but is very rare in biogas-potential studies; thus, we adapt the method proposed by previous studies mentioned above which is widely accepted. All the input costs used—labor cost, capital and machinery costs, skilled labor cost, etc.—are in accordance with the current market prices in Thailand. Two technologies are selected for recycling of solid waste; biogas and compost. The theme here is to explain the costs and benefits of both biogas and compost plants, thus determining the applicability and suitability of the best option to manage waste on a sustainable basis.

The following simple formulas were used for the calculation:

Cost Benefit = Total benefits- total cost

The return period for investment cost was also calculated by the following method:

Return period for investment cost = Investment cost / Return Benefit/Year

The BCR is calculated as the total benefits divided by the total costs:

$$BCR = \frac{\sum_{r=1}^{r} B_t / (1+r)^2}{\sum_{r=1}^{r} C_t / (1+r)^2} \qquad \text{.....................(1)}$$

Results and discussions

Current solid waste practices in the market are quite traditional and simple, i.e. collection, transfer, and disposal. Management inefficiency has been observed to be a big challenge in managing solid waste within the market and especially in the public areas which are out of the vendors' vicinity. The whole waste collection and disposal contract is handled by a private company, the costs covered under a reasonable budget. Figure 2 explains the current waste flow of the market. Figure 3 shows the current solid waste composition of the market. Simple benefit-cost analysis for both proposed technologies (biogas and compost) showed that biogas is the best solution to manage the organic waste as compared against the composting technique.

It is further concluded that the administration of Talaad Thai needs partnership to invest in a green waste-to-energy conversion scheme to manage the solid waste. Partnership is needed because the market itself is unable to start such a green business venture due to lack of financial assets and skilled labor. They need both financial partnership and institutional help as well.

As explained earlier, both before and after situations are adapted to conduct this BCA. The information on waste disposal revealed that almost 75% of fruit and vegetable waste is dumped into the landfill every day. A total of 80% organic waste is dumped into the nearby landfill. In this way, approximately ¼ of the total income of the market is being invested in waste management and related activities of the market. Unfortunately, all the organic waste from Talaad Thai—except for a few kilograms of vegetable leaves (which are sold to the local people as animal feed)—is dumped into landfills. Although Talaad Thai does not own any landfill sites, the management contracts private landfill sites situated almost 60 kilometers away from the market. Nearly 150 people are engaged in cleaning, collecting, and disposal. Similarly, a total of 12 trucks are appointed for waste handling from the market to the Bangsai disposal site (in another province). From the 12 trucks, 6 are used for the collection and transfer of waste within the market itself, while 6 are used for outside transfer, that is, for transporting solid waste from the market to a disposal site in Ayutthaya province (Angkanawatana, 2009).

It is found that under the current situation the market is investing almost 10 million Thai Baht (THB) annually to sweep the waste out of the market. Hence, by ceasing to dump waste into the landfill the budget for waste disposal can be reduced to 80% of what is currently being invested. This is first-hand saving (8,03,000 THB) that can be achieved by adapting either technology. Afterwards, comparative analyses for biogas and compost technologies are made to consider the best option to recommend.

In the case of Talaad Thai, we propose a biogas plant with a single-stage wet system, with a carrying capacity of almost 1,000–110,000 tons of waste annually. Specifically, the biogas production technology works on anaerobic digestion (AD). The process of AD to produce biogas is quite common, and although it varies from country to country, it is well understood in the research community. The number of plants would depend on the amount of waste generated in the market, and this would be a single stage system especially for green waste. The single-stage wet system performs optimally at 35 °C or 95 °F, which best suits the climate in central Thailand. The BCAs for both biogas and compost technologies are elaborated in Table 1 and 2. The benefit-cost ratios for compost and biogas technologies are higher than the current ratios and among these two technologies, biogas is presided. A comparative overview of both technologies is explained in Table 3. There should also be provision of environmental awareness to the vendors' community to facilitate the efficient application of solid waste management techniques in the market, as vendors cannot be expected to perform—or even consider—proper waste management until they are made well aware of its importance. Public private partnership can be a new and effective plan for sharing budget burdens and to provide other institutional, operational, and technical facilities for managing solid waste in green markets. Such partnerships will not only help to manage solid waste effectively, but also to introduce market products internationally, especially those products in which public agencies will hold shares, like composts or different by-products. Furthermore, this sustainable solid waste management in Talaad Thai would not only minimize the waste burden of the market but will be an example for rest of the green markets of Thailand and other Southeast Asian countries having similar issues in waste management.

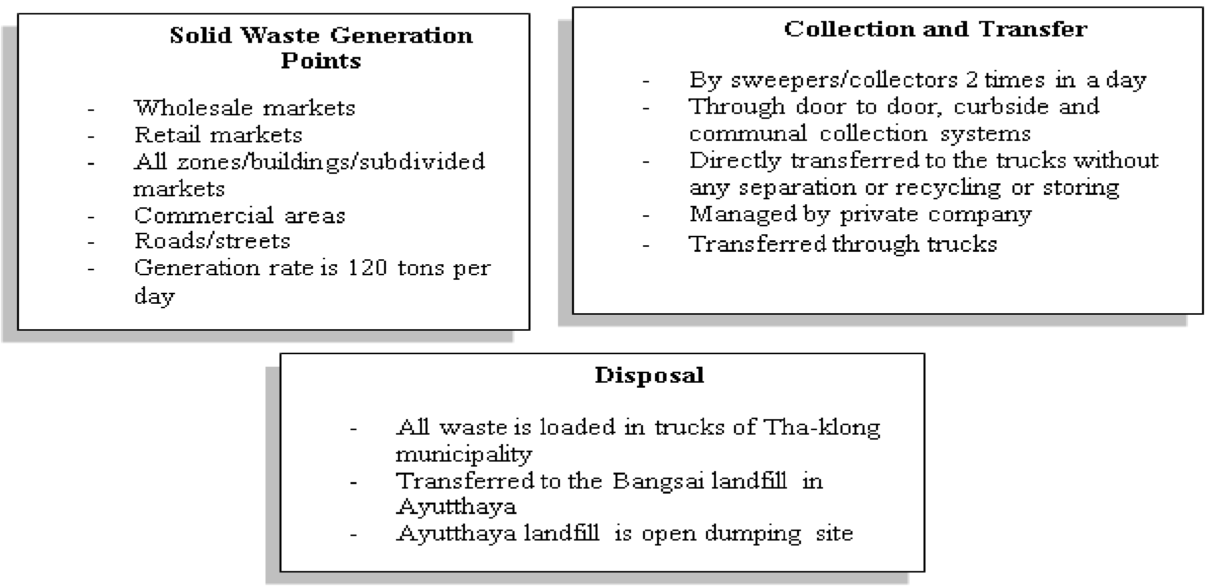

Fig. 2. Solid waste generation, collection, and disposal system of market.

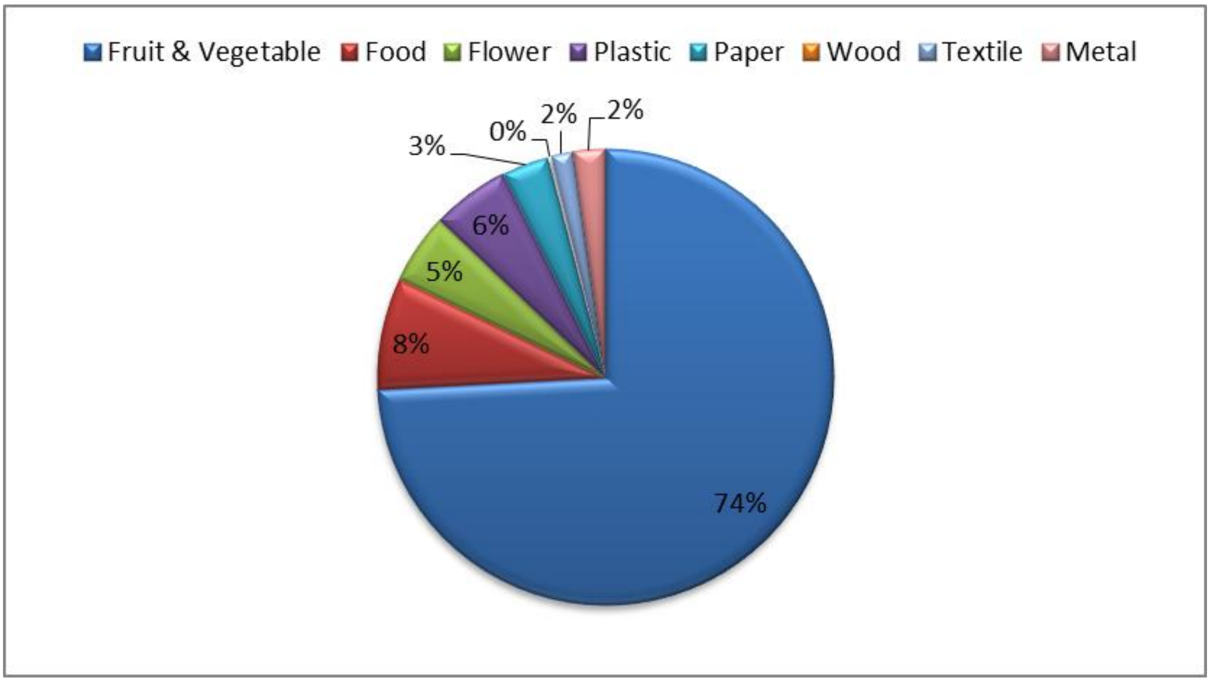

Fig. 3. Solid waste annual trends of the market; Source: Angkanawatana, 2009

Table 1. Benefit-cost of biogas plant of market

Investment *cost		**Operation and maintenance cost**		**Benefits**	
Construction	1,000,000	Unit cost per ton	2500	Unit cost per ton	12,000
Working capital & contingency	1,000,000	Total waste quantity (tonnes)	29.4	Total biogas quantity (tonnes)	15.1
Process equipment & machinery	1,500,000	Total cost per day	73,500	Total income per day	1,81,200
**Fees	500,000	Total cost per annum	**26,827,500**	Total benefits per annum	**66,138,000**
Total	**4,000,000**				

**Fees of local consultants, bio-works and authority submissions *All figures are given in Thai baht (THB)

Conclusion

The main objective of this study was to conduct comparative benefit-cost analysis of two recycling technologies for the largest green market of Thailand. Hence, after performing the benefit-cost analyses for each scenario, it can be concluded that an administrative adaptation of the market to include biogas production is clearly the best suitable option for solving Talaad Thai's current solid waste management issues. A potentially significant comparative advantage of biogas over compost is the marketing potential and acceptability of this renewable energy source among the masses. Biogas is already a widely accepted technique, as compared to compost, which is currently only accepted for agricultural and gardening usage in the community. For both the biogas and compost units, benefit-cost analyses have been estimated using similar scenarios, units, formulas, and conditions so that reasonable comparison may be made, resulting in a clearer understanding of the issue.

Consequently, it can be concluded, on the basis of above benefit-cost analyses, that biogas is the best economical and rational technology for adaptation by the market to solve the solid waste management problems, while also providing the best financial prospective through potential partners, as the market is currently not able to launch such a program individually. Therefore, it can be determined that biogas is the best renewable energy option for the market at this time.

Table 2. Detailed estimation and analysis for biogas plant

Benefits and costs	Estimations	Total
Total cost of biogas per annum	26,827,500	-
Total benefits from savings and biogas production	8,03,000 + 66,138,000	THB 66,941,000
Gross return per annum = Total benefits – Total costs	66,941,000 – 26,827,500	THB 40,113,500
BCR = Total benefits/Total costs	66,941,000 /26,827,500	2.49
Investment cost for biogas plant	THB 4,000,000	-
Return period for investment cost	4,000,000/40,113,500	~1 years

Table 3. Benefit-cost of compost plant of market

Investment *cost		**Operation and maintenance cost**		**Benefits**	
Construction	1,000,000	Unit cost per ton	3200	Unit cost per ton	10,000
Working capital & contingency	1,500,000	Total waste quantity (tonnes)	14.4	Total compost quantity (tonnes)	8.1
Process equipment & machinery	1,000,000	Total cost per day	46,080	Total income per day	81,000
**Fees	500,000	Total cost per annum	**16,819,200**	Total benefits per annum	**29,565,000**
Total	**4,000,000**				

*All figures are given in Thai baht (THB)
**Fees of local consultants, bio-works and authority submissions etc.

Table 4. Detailed estimation and analysis for compost plant

Benefits and costs	Estimations	Total
Total cost of compost per annum	THB 16,819,200	-
Total benefits from savings and compost production	8,03,000 + 29,565,000	THB 30,368,000
Gross return per annum = Total benefits – Total costs	30,368,000 – 16,819,200	THB **13,548,800**
BCR = Total benefits/Total costs	13,548,800/16,819,200	**0.80**
Investment cost for compost plant	THB 4,000,000	-
Return period for investment cost	4,000,000/30,368,000	**~1 years**

Table 5. Comparative advantages of biogas vs compost in Talaad Thai market.

Benefits	Biogas	Compost
Reduction in Waste	Yes	Yes
Income	80% more than costs	Equal to costs
Investment Cost	Same for both	Same for both
Environment Friendly	Yes	Yes
Investment Cost Return Period	~ 8 months	~ 13 months
Land requirement	Same for both	Same for both
Skilled & Technical Labor	More Required	Less Required
Marketing of Product	High market value product	Marketing is main Part for Income
Labor Requirement	Less Required	More Required

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