International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume-2, Special Issue 8 (Nov-Dec 2014), PP. 07-14

THE ECONOMIC BENEFIT OF ENERGY GENERATION FROM REFUSE- DERIVED FUEL FROM SANITARY LANDFILLS IN SOUTH THAILAND

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Abstract: This research aimed to assess the viability of energy generation from refuse-derived fuel from sanitary landfills in Songkhla and Phatthalung provinces in Southern Thailand using an environmental economics model. All externalities were taken into consideration and evaluated. The information in this study can inform decision making about solid waste disposal in municipalities in Songkhla and Phatthalung provinces.

The research found that solid waste embedded in landfills for at least seven years is most suitable for use as refuse-derived fuel. When external costs and benefits were taken into account, the present value of the total cost of an incineration plant with a capacity of 250 tons/day and a lifetime of 20 years was 2.55 billion Baht and the total benefit was 3.80 billion Baht. The net present value (NPV) at a discount rate of 12 percent, and a project life of 20 years, was 1.19 billion Baht and a positive benefit-cost ratio of 1.43 was calculated suggesting that the project is economically viable. Sensitivity analysis conducted on the external cost calculations, produced a positive NPV in all cases except in the case of a 20% increase in costs and a 20% reduction in benefits. Based on this study, Songkhla City Municipality should consider constructing an incineration plant which could generate energy from refuse-derived fuel. Although, to do so may require high expenses, when taking into consideration the social benefits, it was found that the intangible benefits would more than cover the costs.

Keywords: cost-benefit analysis, environmental economic assessment, environment impact valuation, externalities, refuse-derived fuel (RDF), incineration plant

1. INTRODUCTION

Solid waste has become a real environmental problem which every community, from small to large, has to face. This results from the rush for economic development and population increase. In Thailand, 64% of solid waste is disposed of by dumping it on open fields and burning it; 35% is disposed of in sanitary landfills and 1% by incinerator [1]. This paper is focused on waste disposal in sanitary landfills which has hitherto been the most appropriate means of waste disposal for Thailand. However, the use of sanitary landfills also has some limitations, particularly the fact that land for use as landfills is scarce and nearby households do not appreciate having landfills close to their communities. This has proved to be a problem in Thailand and several communities have protested strongly about landfills.

Songkhla City Municipality is one of many municipalities who have faced this challenging issue. The municipality has used sanitary landfills since 1999 and up to now 140 rai of land has been used to accommodate waste [8]. New land has been prepared for a new landfill, but protests by the people nearby have created difficulties. Therefore, the municipality is seeking a new method to handle the increasing quantities of solid waste. One of the alternatives is to use waste to generate energy based on refuse-derived fuel (RDF) from sanitary landfills in Songkhla and Phatthalung provinces. Incinerating solid waste and using the heat derived to produce electricity as a renewable resource will remove the need to use more land for landfills. Using waste as a material for generating energy is little tried in Thailand. In the South, there is only one such scheme in Phuket Municipality, on the West coast of Thailand. On the East coast there are none. Considering all the possible methods of dealing with waste, especially the implications for political security, the use of solid waste as RDF to generate power in Songkhla and Phatthalung provinces has a high potential.

In Songkhla Province there are 4 sanitary landfills which are in Songkhla City Municipality, Hat Yai Municipality, Ban Pru Municipality, and Sadao Municipality. In Phatthalung Province, there is one sanitary landfill which is in Muang Phatthalung Municipality. The aim of this study was to carry out a cost-benefit analysis of electricity generation from solid waste, taking into consideration its environmental impact. In this study we calculated the cost-benefit of using landfill waste from these 5 landfills as RDF, assuming that the power plant was situated in Songkhla Municipality. The analysis also considered social costs and benefits.

2. RESEARCH METHODOLOGY

A review of the literature showed that there have been very few studies in Thailand which calculated the benefit of using waste from landfills as RDF. Most of the studies traced took into account purely a financial perspective and did not include the environmental impact. For example, the study of the feasibility of various physical locations for an incinerator in the Eastern part of Thailand [2] and the case of waste disposal cost using an incinerator in Chiang Mai [14]. However, using incinerators raises environmental issues entailing costs and benefits to society as a whole and these are often not accounted for in financial analyses. Apart from the two studies cited above, there have been no studies in Thailand on reusing landfill waste to generate energy. The

research closest to this subject conducted analysis at how to process the community's solid waste into replaceable energy [7].

Due to the limited previous research on this subject, the authors were interested in assessing the costs and benefits, including externalities, of using landfill waste as RDF to generate energy. This research was conducted in the study areas of Songkhla City Municipality, Hat Yai Municipality, Sadao Municipality, Banphru Municipality and Phatthalung City Municipality. In the South of Thailand, only Phuket Municipality generates energy using RDF from sanitary landfills [6]. Songkhla Municipality does not yet have such a project. Therefore, in order to study the viability of using solid waste to generate energy in Songkhla Municipality, data was collected from Phuket Municipality and the findings applied to the study area because at the Phuket sanitary landfill and incinerator, the actual external costs and benefits which accrued to society have already been assessed. Therefore, this research used the benefit transfer method to assess whether building an incinerator in Songkhla would be economically viable if all externalities were taken into consideration.

A. Assessment of impact area of air pollution

The area impacted by air pollutants can be determined using a Gaussian distribution, a method widely used to study the distribution of pollutants [15]. The following equation (1) was used:

$$X(x,y,zH)=\frac{Q}{2\pi\sigma_y\sigma_z U}\times[e^{(-\frac{y^2}{2\sigma_y{}^2})}]\times[e^{(-\frac{(z-H)^2}{2\sigma_z{}^2})}+e^{(-\frac{(z+H)^2}{2\sigma_z{}^2})}] \quad (1)$$

Considering the concentration of pollutants from the incinerator, it was found that the highest concentration of between 1.19*10-7 – 1.1*10-8 g/m3, would be found at distances between 300m and 3km from the plant (Fig. 1). According to the ambient air quality standard, the ambient air quality should be between 3.0*10-4 g/m3 [3]. Thus, from the data in Table I, the concentration of Sulfur dioxide would not exceed the standard level. However, the area within 3 kilometers from the incinerator was covered in the survey.

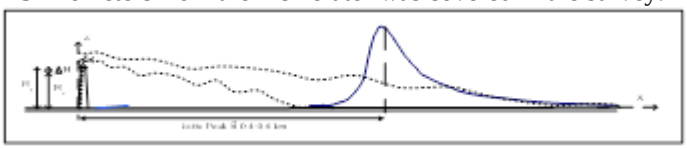

Fig. 1 Distance where the levels of pollutants from incinerator were measured.
Source: [9]

Table I Relationship between distance and sulfur dioxide concentration

Distance (km)	Sulfur dioxide concentration (g/m^3) Stability class type B
5.0	$3.86*10^{-9}$
4.5	$4.52*10^{-9}$
4.0	$5.89*10^{-9}$
3.5	$7.64*10^{-9}$
3.0	$1.1*10^{-8}$
2.5	$1.5*10^{-8}$
2.0	$2.5*10^{-8}$
1.5	$3.9*10^{-8}$
1.0	$8.0*10^{-8}$
0.9	$9.7*10^{-8}$
0.8	$1.15*10^{-7}$
0.7	$1.39*10^{-7}$
0.6	$1.64*10^{-7}$
0.5	$1.84*10^{-7}$
0.4	$1.78*10^{-7}$
0.3	$1.19*10^{-7}$
0.2	$1.7*10^{-8}$
0.1	$8.43*10^{-13}$

From the ambient air quality standard [3], the ambient air quality should be between 3.0*10-4 g/m3. From the calculation, it was found that within a radius of 1-5km from the incinerator, the level of sulfur dioxide concentration did not exceed this standard.

B. Population, sample size and sampling method

The study population was the households who suffer impact from pollution generated by the incinerator in Phuket Municipality. The use of this population allowed the calculation of the external health cost of the incinerator. The Sample size was 182 households. The households were randomly selected using systematic

random sampling. Initially, the population was divided to attain a sampling interval. A random starting point was then selected and choices thereafter were at regular intervals until 182 households were selected. Ten per cent of the questionnaires were treated as spare.

C. ***Research steps***

- Technical survey: Data was collected from observation, personnel interviews and a literature review. These included:
  1) Quality, physical and chemical composition of solid wastes.
  2) Calorific value and conversion to financial value.
- Economic assessment:
  1) Cost - benefit analysis of the project, including positive and negative externalities.
  2) Screening of the externalities to be valued, as in Fig. 2, Table II and III.
  3) Calculation of net present value.

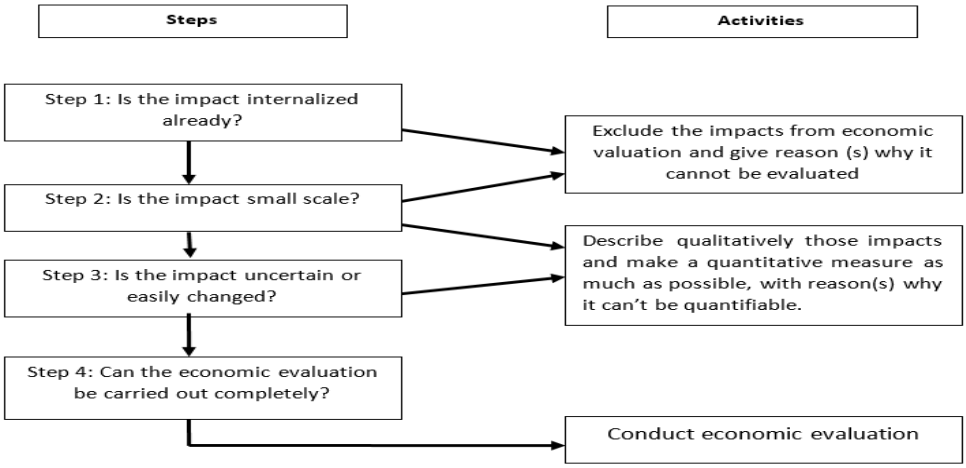

Fig. 2 Screening of externalities
Source: [4]

Table II Costs and benefits of externalities from incineration

Cost/Benefit	Impact
SO_2	(-)
NO_x	(-)
CO	(-)
HCl	(-)
Oxidants (ozone)	(-)
PCDDs/PCDFs	(-)
Heavy ash/heavy metals: As, Cd, Cr, Pb, Hg, Se, Ag	(-)
Dust larger than 10 microns (PM10)	(-)
Dust smaller than 10 microns (PM10)	(-)
EMR	(-)
Change in global temperature	(-)
Climate change	(-)
Odor	(-)
Noise in the building and within the incinerator area	(-)
Change in water temperature around the area	(-)
Heavy metal contamination from ash	(-)
Conflicts among different groups of people near the incinerator	(-)
	(-)
Loss of landscape beauty at landfill site	(+)
Cost reduction for purchasing new land to construct landfill sites	(+)
	(+)
Use of old landfill to carry out other projects	(+)
Reduction of conflicts over new land for more landfill sites	
Reduction of negative externalities from landfill sites	

Table III Summary of environmental impacts evaluated and evaluation methods

Environmental impacts	Evaluation methods
1. Environmental health of people	Human Capital Approach: collect data from people living within 3 km. from incinerator who have suffered disease associated with oxidants and dioxin.
2.Reduction of purchasing cost for new land to construct landfill site	Using the municipalities' projected costs, discounted into present value, for preparing new landfill sites in the next 20-25 years if the present capacity becomes full.
3. Use of old landfills to carry out other projects	Opportunity Cost approach
4. Reduction of negative externalities from landfill	Benefit Transfer Approach: using data from Srisamai (2005) with the value adjusted for this study

3. RESULTS

The costs and benefits of an incineration project over a period of 20 years are detailed below

A. The cost of the project comprised three main areas: fixed costs, operation costs and negative externality costs.

1) The fixed costs include the cost of construction of the building and the heavy equipment such as the solid waste receiving pond, incinerator, boiler, electricity installation, measuring equipment. The net present value of the investment cost was 15.98 billion Baht.

2) The operation costs include wages, consultation cost, fuel, chemicals, and materials relating to the operation of the incinerator. The net present value of the operation costs for a 20-year project were evaluated at 10.05 billion Baht.

3) The externality costs covered all negative effects impinging on third parties in society which would lower their quality of life. Consideration of the possible impacts suggested that there is only one negative impact that could affect lives: PCDDs/PCDF pollutants. Evaluation was conducted in the area of the Phuket incinerator using the human capital approach and a health cost of 15,796.40 Baht per year was arrived at. This value was then transferred using a benefit transfer approach from the incinerator site in Phuket Province to the study site in Songkhla province). This was done by calculating the health cost per GPP in Phuket and then converting it to a figure based on the GPP in Songkhla. A total cost of 34,180.30 Baht per year was calculated.

B. The benefit of the project was calculated from 5 components: sale of electricity, waste disposal fee, products from fly ash, sales of recyclable materials and external benefits.Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

1) Sale of electricity

Electricity generated from the incinerator using RDF could be sold to the Electricity Generating Authority of Thailand. The energy content of the electricity assumed in this study to be capable of generation was calculated using the improved Dulong's equation (Tchoanoglous *et al*, 1993):

Btu/lb=145C + 610 (H - 02/8) + 40S + 10N (2)

In order to calculate the energy as in equation (2), the characteristics of the waste from 5 municipalities were considered, i.e., their physical properties and chemical composition including moisture, nitrogen, phosphorus, potassium, carbon and hydrogen. From the data collected, it is expected that all landfill refuse will be used as fuel in the incinerator between project years 3-13. Then in years 14-20 the fuel for the incinerator will be waste collected daily and delivered directly to the incinerator without the need for further use of landfill sites. Table IV shows the details of this calculation.

The energy efficiency of the incinerator based on the excess electricity after internal use within the incinerator site was initially estimated to be 27.2%. However, based on reports from Phuket Municipality, only 66% of the electricity produced is used within the incinerator building leaving 34% to be sold to the Electricity Generating Authority of Thailand at a rate of 2.50 Baht/kWh for the project years 1-5 and at a rate of 2.10 Baht/kWh in years thereafter. This is shown in Table V.

Table IV Chemical equation of refuses and wastes and energy content

Municipality	Chemical equation of refuses (Project year 3-13)	Energy content (kJ/yr)	Chemical equation for daily wastes (project year 14-20)	Energy content (kJ/yr)
Songkhla	$C_{513.5}H_{950.7}O_{335.5}N_{15.4}S$	430,085,642,161.70	$C_{509.1}H_{2441.9}O_{1089.8}N_{15.3}S$	168,390,418,396.07
Hat Yai	$C_{484.99}H_{899.54}O_{320.23}N_{14.89}S$	904,387,663,273.78	$C_{480.86}H_{2314.30}O_{1035.83}N_{14.76}S$	407,915,077,838.72
Phatthalung	$C_{405.81}H_{763.53}O_{283.62}N_{14.77}S$	58,223,408,372.82	$C_{406.82}H_{1998.25}O_{906.88}N_{14.81}S$	41,879,919,608.96
Sadao	$C_{423.82}H_{792.94}O_{290.15}N_{15.22}S$	27,519,028,322.46	$C_{419.22}H_{2046.97}O_{924.37}N_{15.09}S$	19,786,796,061.24
Ban Phru	$C_{872.98}H_{1498.98}O_{468.32}N_{22.02}S$	47,063,534,729.33	$C_{872.73}H_{3800.39}O_{1630.62}N_{22.01}S$	31,114,012,317.82
Total energy (kJ/yr)	-	**1,467,279,276,860.08**	-	**669,086,224,222.81**

Table V Revenue from the sale of electricity

Source of energy	Electricity produced (kWh) (1)	Used within the incinerator building (kWh)[1] (2)	Electricity sold (kWh) [2] (3)	Price (Bt/kWh) (4)	Revenue (Bt/yr)[3]
Refuse from years 3-8	110,861,100.92	73,168,326.61	37,692,774.31	2.50	**94,231,935.78**
Refuse from years 9-13	110,861,100.92	73,168,326.61	37,692,774.31	2.10	**79,154,826.06**
Daily collected waste in years 14-20	50,553,181.39	33,365,099.71	17,188,081.67	2.10	**36,094,971.51**

2) Waste disposal fee.

A Waste disposal fee could be collected from municipalities who want to dispose of their waste in the incinerator. The fee assumed in this study was 200 Baht/ton waste.

Thus the revenue from the waste disposal fee can be calculated as in Table VI.

Table VI Waste quantity and waste disposal fee from each municipality

Municipality	Waste quantity (landfill refuse) project years 3-13 (ton/yr)[1]	Waste disposal fee (Bt/yr)[3]	Waste quantity (daily waste collection) project years 4-20 (ton/yr)[1]	Waste disposal fee (Bt/yr)[3]
Songkhla	22,046.97	-	18,100.63	-
Hatyai	46,736.11	9,347,221.09	44,189.48	8,837,896
Phatthalung	3,142.45	628,489.30	4,727.57	945,514
Sadao	1,464.44	292,888.22	2,203.14	440,628
Ban Phru	2,180.37	436,074.76	3,029.32	605,864
Total waste fee collected		**10,704,673.38**	-	**10,829,902**

3) Produce from fly ash.

Fly ash from incineration can be used to produce concrete. Based on the previous study [5], 864,000 kg/day of fly ash would be produced from the incinerator sufficient to manufacture 21,600,000 concrete blocks/year (using 20% fly ash in place of cement by weight which is in accordance with industrial standard no. 58-2530). This would generate revenue of 8,424,000 Baht/yr.

4) Sale of recyclable materials.

When a landfill which has been in use for more than 7 years is raked up, the refuse must be separated before being put into the incinerator [10]. Some of the materials separated can be sold as recyclable materials, for example, metal and glass. Revenue from this was calculated for project years 3-13 at 93,810,408.71 Baht/year and for project years 14-20 at 378,579,242.70 Baht/year

5) External benefits.

External benefits are defined as positive returns from activities that enhance society and the environment. There were three external benefits determined in this study, as follows:

- The project would save the cost of the provision of land and the construction costs of a new landfill area to replace the current landfill when it is full. This saving in cost is thus an external benefit of the project. The present value of this cost saving was 1,702,248,830.53 Baht, from 5 municipalities throughout the 20 years of the project.

- Since the project would reduce the current landfill area, the area saved could be used for other purposes. Thus the opportunity cost of reducing the landfill area can be regarded as an external benefit. The two most plausible alternatives determined in this study were to use the land for rubber plantations or as a recreational area. Of these, the benefit from a recreational area was higher, and this was adopted as an opportunity cost (or external benefit in this case). The opportunity cost of a recreation area for the project, using the benefit transfer method [11] was calculated at 21,471,607 Baht in years 3-13 and for project years 14-20 at 30,290,107.60 Baht.
- There would be external benefits from reduced external costs when changing from using landfills to incineration. The externalities inherent in the use of landfills notably include odour, leachate, groundwater contamination, and these forms of pollution would be lessened by reducing the area of landfills. All the municipalities involved would gain such benefits. Using the monetary Figs for these externalities calculated [12], the external benefit calculated to accrue for project years 4-20 was 1,138,459,692,34 Baht per year. All the costs and benefits of this project are shown in table VII.

C. In conducting the net present value (NPV) analysis, the NPVs, of the external costs and benefits were calculated at discount rates of 12%, 10% and 8%, which produced positive values in all cases of respectively 1.19, 1.80 and 2.63 billion Baht. Similarly, the benefit-cost ratio (BCR) analysis produced positive Figs in all cases of 1.43, 1.60 and 1.81 billion Baht respectively as shown in table VIII. Clearly therefore, Songkhla City Municipality should consider constructing an incineration plant that can generate energy from RDF.

Table VII Total costs and benefits of the incinerator project for 20 years

Costs/Benefits	Value
Total cost	
1. Investment cost (Net present value at year 20)	1,598,329,548, Baht 1,005,729,117 Baht
2. Operation cost (Net present value at year 20)	35,844.99 Baht/year
3. External cost	
3.1 health cost	
Total benefit	
1. Electricity sale	
- years 3-8 using RDF	94,231,935.78 Baht/year
- years 9-13 using RDF	79,154,826.06 Baht/year
- years 14-20 using new waste	36,094,971.51 Baht/year
2. Waste disposal fee	
- years 3-13 using RDF	10,704,673 Baht/year
- years 14-20 using new waste	13,844,164 Baht/year
3. Products from fly ash	8,424,000 Baht/year
4. Sale of recyclable materials	
- years 9-13	93,810,408 Baht/year
- years 14-20	378,579,242 Baht/year
5. External benefits comprising of	778,720,712 Baht
5.1 the value of supplying and constructing a new land site (Net present value at year 20)	
5.2 Value accruing from transforming landfill sites to other purposes	21,471,607 Baht/year 30,290,107 Baht/year
- years 9-13	1,138,459,692 Baht/year
- years 14-20	
5.3 Benefit values of reduced external impacts	
- years 14-20	

Table VIII Net Present Value Analysis and Benefit-Cost Ratio

Discount rates	Net Present Value Analysis (NPV)	Benefit-Cost Ratio (BCR)
8%	2,639,741,366.40	1.81
10%	1,805,591,356.80	1.60
12%	1,194,637,663.68	1.43

D. Sensitivity analysis is the study of how the variation (uncertainty) in the output of a model can be attributed to variations in the accuracy of inputs to a model. To conduct this analysis the incineration plant was assumed to have either a capacity of 250 tons/day or 150 tons/day. The first option was based on the 250 tons/day capacity of the existing incinerator in Phuket. The second option of 150 tons/day was adopted because this production capacity accords with the amount of available municipal solid wastes aged 7 years or more which gain high thermal energy. The details are presented in table IX below.

Table IX Sensitivity analysis

With capacity of 250 tons/day	With capacity of 150 tons/day
(1) 5%-30% increased cost and constant benefit	(1) 5%-30% increased cost and constant benefit
(2) constant cost and 5%-30% increased benefit	(2) constant cost and 5%-30% increased benefit
(3) constant cost and 5%-30% reduced benefit	(3) constant cost and 5%-30% reduced benefit
(4) 5%-30% increased cost and 5%-30% reduced benefit	(4) 5%-30% increased cost and 5%-30% reduced benefit
NPV showed to be positive in all cases Except with 20% increased cost and 20% reduced benefit	NPV showed to be positive in all cases Except with 20% increased cost and 20% reduced benefit

4. DISCUSSION

a. If the capacity of an incinerator built in Songkhla was 250 tons/day, Songkhla City Municipality would have to allocate a higher budget for incineration than for sanitary landfills. In order for Songkhla City Municipality to be able to use incineration at a lower budget than it currently allocates to landfills, the size of the incinerator would need to be reduced to 120 tons/day or 150 tons/day. This study shows that even though an incinerator using RDF may have higher initial costs, Songkhla City Municipality should consider building one since the indirect social benefits are higher than the cost. Those intangible benefits are also higher than the external costs that the people near landfill sites have to bear.

b. With an incinerator of a capacity of 250 tons/day, the amount of municipal solid waste from the 5 municipalities would not allow it to reach its full capacity. However, Songkhla City Municipality could accept solid waste from other municipalities which would enhance the efficiency of their solid waste management. Each municipality should commit to improving its own system of solid waste management but there should be collaborate among those municipalities to enhance the efficiency of solid waste removal while also maximizing the effectiveness of limited budgets.

c. At present, Songkhla City Municipality's waste fee is 200 Baht/ton, which is lower than the actual cost of waste disposal. This rate covers only 25 per cent of the total cost, which means that the government has to subsidize the remaining 75 per cent. With this low fee, generators of waste may not be aware of the environmental problems created because they would naturally perceive that this fee already covers the total investment and operation cost. Since this fee is very low, they would be unlikely to take steps to reduce waste because it is cheaper to pay the fee than to manage waste by other means. Thus the Municipality should also motivate generators of waste by using the polluter pays principle to make the party responsible for producing pollution responsible for paying for the damage done to the natural environment. Further, the prevention principle should also be jointly used to protect the environment because preventing environmental harm is cheaper, easier, and less environmentally dangerous than reacting to environmental harm that has already taken place.

d. To increase the effectiveness of their integrated waste management, Songkhla City Municipality should consider investing in a waste sorting plant. This would result in sorted recyclable materials which would not only be capable of producing revenue from the sale of recyclable materials but also improve the efficiency of incineration by reducing the incineration of fresh and plastic waste. Therefore, the municipality should educate people and give them information on how to dispose of and recycle different waste materials by reducing, reusing and recycling. These three key factors are very important to the enhancement of the incineration capability of an incinerator project.

5. SUGGESTIONS FOR FURTHER RESEARCH

- There should be a technical investigation of the physical and chemical characteristics of existing land-fill waste to determine its actual energy content, and also an analysis of the optimum period of storing waste to achieve the highest energy content.

- This study has only considered only 5 sanitary landfill sites as sources of municipal solid waste as a material for generating energy. However, there are other landfills in Songkhla province not identified in this study which could also provide RDF. Using RDF from all landfill sites in Songkhla would save more costs through the optimization of transportation as compared with transporting waste from Phatthalung. Moreover, there are many environmental problems associated with landfills, such as emissions, toxic substances entering the air or water, groundwater contamination and health effects. Those impacts will be reduced by building a waste incinerator instead of using landfills.
- If Songkhla City Municipality decides to consider building an RDF incineration project, it is essential that further detailed studies should be conducted to understand the context, stakeholders' opinions and people's acceptance of, attitude towards and concerns about the project. Most importantly, this should include a public consultation process regarding the benefits and drawbacks of the project.

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