



## A Decade of Waste to Energy Plant of Phuket

Pireeyutma Vanapruk

**Abstract**— Since June 1999, the first Waste to Energy Plant of the country has begun its municipal solid waste disposal service to 18 localities in Phuket Province with 250 ton/day capacity and generated 2.5 MW-electricity. For more than a decade of its service is long enough to give valuable lessons learned to Thai government, localities, and Thai people pro and con of using incinerator technology, technical wise, economical wise as well as formulation of waste management policy. Further more, it could be a good sample for to private sector who intends to share their resources in investment and operation in public facility.

In view of renewable energy, municipal solid waste could possibly be alternative resources or fuel for energy generation. Recently, Thai government has been using financial measure known as Adders to increase buying rate of electricity generated by waste to energy plant. Thereby, it could enhance the financial return of the project to the attractive level. However, based on an experience of Phuket waste to energy plant, it reiterates the necessity of waste separation at sources of generation as the most influence factor of possible and feasible waste to energy project in Thailand.

**Keywords**— Incinerator, waste to energy, adders, waste separation at sources.

### 1. CURRENT SITUATION

The incinerator of Phuket Province has been completely installed and providing solid waste disposal services to all 18 localities as well as private sectors within the province since June 1999. With an annual increasing rate over 10% since 2000, the current amount of solid waste sent to incinerator has been more than 500 ton/day while the disposal capacity is limited at 250 ton/day with 2.5 Mw electricity generation capacity. It could be claimed as the first and only one waste to energy plant using thermal treatment process in the country. [1]

Due to rapid growth of tourism and urbanization, the total waste amount sent to the incinerator exceeded its capacity just after one year of the operation. Phuket Municipality, the largest locality in the province was assigned to undertake the operation, has tried with many possible solutions to reduce waste amount and in the same time to increase the disposal capacity of the incinerator.

In 2000, the Municipality awarded a concessionaire contract to a private company to invest, build and operate a waste separation plant located adjoining to the incinerator. This separation plant was originally designed to receive mixed waste and separate recycling materials before sending the left to incinerator. It was expected that the plant could reduce waste load to the incinerator about 100 ton/day or 30% by weight of 300 ton/day receiving capacity. The main income of the plant was from selling recycling materials but in the actual

operation, the separation plant had never been able to separate recycling materials more than 10% by weight. Figure 1 shows average daily waste amount disposed by incinerator and landfill during 1999-2008[2] comparing to daily amount of the left from separation plant which operated during 2001-2006 before the plant was suspended in August 2006 due to heavy loss of the company.

Considering the increasing of waste amount in Phuket Province, despite the interruption of Severe Acute Respiratory Syndrome (SARS) epidemic in 2003 and Tsunami disaster in 2004, waste amount has remained in the trend of increasing by an average rate of 9-14% per year. In 2005, a year after Tsunami disaster, Phuket and neighbouring provinces were surged into sudden situation and followed by decreasing of tourists. Consequently, the increase rate of waste in 2005 was dropped from 13.7% in the previous year to 3.21%.

To recovery the situation in Phuket, numbers of aid programs from the government including ad hoc budget for refurbishing damaged infrastructures and housing scheme were allocated for Phuket and neighbouring provinces. It resulted very fast recovery of the tourism in Phuket and neighbouring provinces. By the beginning of tourist season in October 2005, large number of tourists returned to their famed destination.

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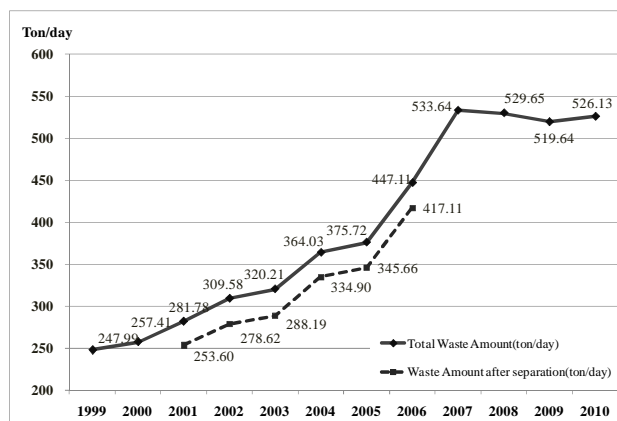


Fig. 1. Average daily waste amount to Phuket Incinerator.

The governmental aid programs and recovery of tourism led to an upsurge of land development, housing scheme particularly in newly developed area along the east coast of Phuket Island where used to be agricultural and fishery zones. Number of foreign workers migrated into the area and then worker-camps have been temporarily built up without sufficient sanitation or safety standards. Inevitably, waste amount hiked to the new record over 500 tons per day with the increasing rate in 2006 and 2007 at 19.03% and 19.40%, respectively.

The felicity of Phuket soon diminished, when the world economic bubble bursted starting from United States of America in the second quarter of 2008 and then followed by political turmoil in the country. Number of tourists has sharply dropped and it resulted in reduction of the total waste amount.

Fig.1 indicates that the incinerator has been operating at over-capacity stage since the early day of its operation. The excessive amount of waste has been dumped into landfill area where originally prepared for final disposal of incinerator residue. Lack of sufficient waste water treatment facility and improper operation, the landfill site caused consequent impacts to the adjoining area and communities by the leakage of leachate, bad odour and insects. In June 2007, leachate spreaded out from landfill site to the nearby canal, caused heavy damage to the villagers' cultivated fishery.

In 2004, the Phuket Municipality requested financial support from the government for installation of the second combustion chamber. In October 2007, the Cabinet turned down the request of municipality but approved the master plan of Phuket waste management, proposed by Ministry of Natural Resources and Environment being guidance to formulate the provincial action plan to solve persistent solid waste problem. The master plan emphasized public participation in waste reduction and separation. However the increasing of disposal capacity was also addressed as an unavoidable solution [3].

## 2. EFFICIENCY OF WASTE TO ENERGY PLANT

The incinerator of Phuket province situated in 21.5 hectare compound consists of an administration office, weighing station, incinerator plant, 16 ha landfill area,

waste water treatment facility and other related facilities. The plant building was originally designed to accommodate 2 units of combustion chamber having total disposal capacity of 2x250 tons per day. Due to limited budget, only single 250 ton/day combustion chamber was then installed and equipped with 2.5 MWe capacity electricity generation unit.

### Efficiency in Disposal and Electricity Generation

In 1993 during the design stage, the waste composition analysis was conducted and it was found that organic composition in mixed waste was 34.42% by weight giving lower heating value(LHV) above 1,800 Kcal/kg.[4] By this LHV, then it was technically feasible for incineration and economically feasible for thermal energy conversion to electricity. Based on the guideline of World Bank for incineration technology, the acceptable average LHV of waste should be above 1,600 Kcal/kg but not be less than 1,400 Kcal/kg in any season.[5]

According to the actual operation, even though the waste loading has been over the capacity but the electricity generated by the incinerator has been only 1.6-1.8 Mw which is 30% less since the operation started in 1999. It could be explained that LHV of solid waste has been lower than the design criterion.

Increasing of organic composition particularly moist food waste contributed the decline of LHV of solid waste in the province. Table 1 indicates organic composition as the result of different analysis made in certain year. Increasing of organic composition was the result of 1) increasing of number of tourists as shown in Fig.2 showing the annual increasing of number of tourists except in 2005, a year after Tsunami disaster and 2) decreasing of number of pigery.

Table1: Organic solid waste in Phuket province

Year	Reference	Organic Waste(%)
1993	Feasibility Study for construction of the Incinerator [4]	34.42%
1997	Waste Analysis Report prior the operation [6]	38.53%
2000	Annual Waste composition analysis during the operation [7]	45%
2003		49.87%
2004	Waste analysis for the Study of Improvement of Waste Management of Phuket [8]	63.57%
2007	Waste analysis for all municipalities countrywide [9]	59.53%

In the early days, food waste was collected and traditionally used as livestock feed especially for swine or pig. This was similar to a natural symbiosis and food waste could not cause any impact to the environment.

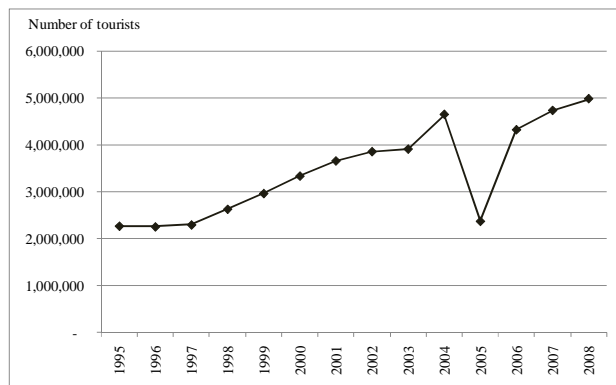


Fig. 2. Number of tourists to Phuket[10]

Due to the tourism promotion and urbanisation, most of suburban area in Phuket province has been developed to be tourist resorts, hotels, housing projects and commercial compounds. The pigeries were forced to stop and the owners were to sell their land or otherwise moved to other neighboring provinces where land was much cheaper. It resulted the number of swine in Phuket province reduced as shown in Fig.3.

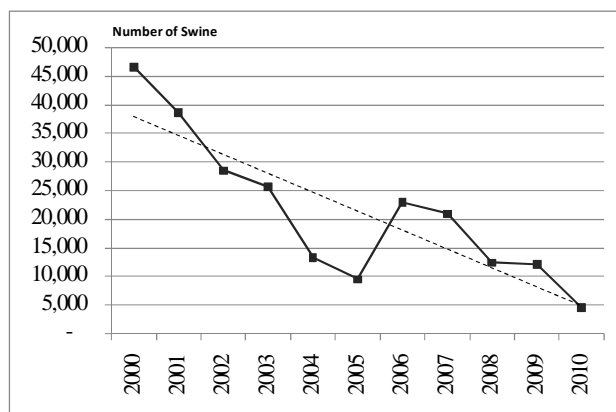


Fig. 3. Number of Swine in Phuket Province [11]

Eventually the excessive food waste has returned to the main waste stream and been collected and sent to incinerator.

Not only food waste which contributes the deficiency of the incinerator, other inert or incombustible fractions could also make the same result. In 2007, glass composition particularly beverage glass bottle was found sharply increasing to more than 10% by weight from its normal range of 3-4%. It was because of the upsurge of oil price and increasing of cost of transportation. In Thailand, most of glass recycling industries locate in central region. Whenever cost of transportation escalates, then the buying rate of glass at local junkshops will decline and dissuade people to separate glasses. All glasses will be collected and finally sent to the same incinerator.

Based on modified Dulong Formula[12] the lower heating value of waste can be calculated by using waste composition.

$$HHV = 80.60C + 339.10(H - O/8) + 22.20S + 5.56N \quad (1)$$

$$LHV = HHV - 583(W + 9H) \quad (2)$$

where HHV refers to High Heating Value (Kcal/kg) C, H, O, S, N, W refer to Carbon, Hydrogen, Oxygen, Sulfur, Nitrogen and Water Content percentage by weight.

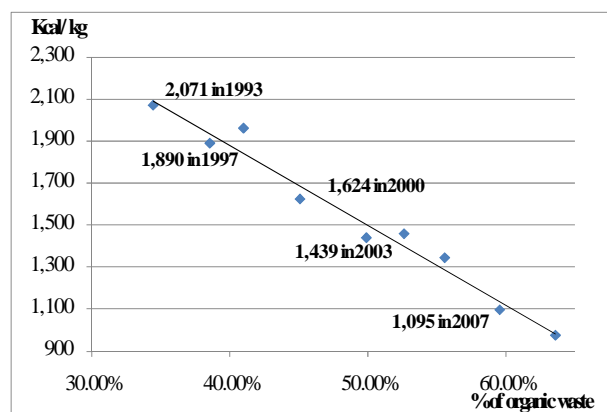


Fig. 4. LHV of solid waste and organic composition.

The increasing of organic composition contributes the slipping of LHV as shown in Fig. 3. and results lower electricity production and inefficient combustion. The incinerator has generated 12,800 MWe-hour electricity product per annum which was 30-40% less while the amount of unburned residue and ashes was 25-30% by weight of loading waste amount, higher than the designed value.

#### Pollution Control

Pollution control is the most public concern issue for the solid waste incineration. Therefore, the operation must be managed in such a way that it will not cause any harm or damage to surrounding environment and quality of life of community. Incinerating municipal solid waste generates large volumes of flue gases. The flue gases carry residues from incomplete combustion and a wide range of pollutants. The pollutants and their concentration depend on the composition of the waste incinerated and the combustion conditions. Ash, heavy metals, and a variety of organic and inorganic compounds can be found in varying quantities.[5]

In case of Phuket incinerator plant, emitted air pollution was inevitable due to incomplete combustion of low heating value and high moist waste. In 2005, gas samples were collected from the chimney, and analyzed, by SGS (Thailand) Company as annual monitoring measure. The quantity of Dioxins and Furans gas was found at 2.13 ngTEQ/Nm<sup>3</sup> [13] against the allowable concentration 0.5 ngTEQ/Nm<sup>3</sup> as per the national emission control standard for solid waste incinerator. Formation of such gases is the result of incomplete combustion of materials containing organic carbon and chloride which are usually found in mixed solid waste such as PVC (Polyvinyl Chloride)[14]. Generally the emissions could be controlled by either restricting their formation, or by controlling combustion temperature so that it does not fall below 800°C [15], but it is not possible for Phuket incinerator due to high moisture content organic waste.

Water pollution was also noted. The excessive waste

amount has been dumped into the landfill since 2002 without proper landfill operation. The leakage of leachate from landfill site to the adjoining natural water canal caused massive death of cultivated fishes in June 2007. It reveals the weakness in pollution control of the plant operator.

**Operation Cost**

For the operation of Phuket incinerator, the operation budget (income of the plant) can be categorized based on 3 different sources, 1) disposal service fee which was 300 Baht/ton and increased to 528 Baht/ton from the fiscal year 2010[16], 2) electricity sale and 3) subsidy from Ministry of Interior which has been a major portion, contributing 65-70% of total operation budget until 2010 when the subsidy was cancelled.

Table 2 is the balance sheet of the plant, being compiled and reformatted from the scattered information concerning cost and income of the plant with the assistance of Sanitary Engineering Bureau, Phuket Municipality. It indicates that, the operation cost of the plant for 2003 and 2004 are 657.73 and 818.07 Baht/ton respectively.

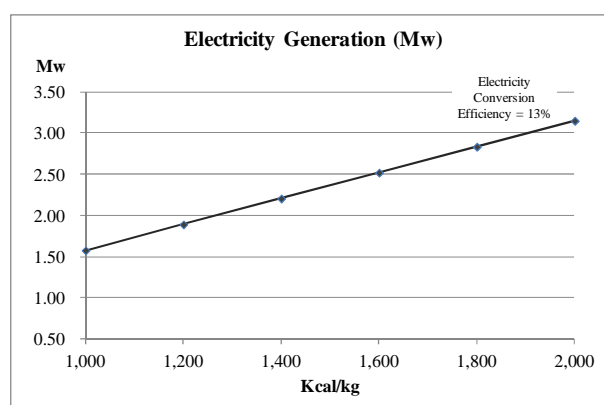
**Table 2: Balance Sheet of the Plant for 2003 and 2004**

	Amount(1000xBaht)	
	2003	2004
<b>Incomes</b>		
- Subsidy from Government	39,000	53,000
- Disposal Fee	17,032	18,775
- Electricity Sale	2,222	6,085
<b>Total Incomes</b>	<b>58,254</b>	<b>77,860</b>
<b>Costs</b>		
- Operation Contract	37,125	38,416
- Water supply	589	515
- Electricity	642	1,719
- Fuel(Diesel)	970	315
- Lime	3,384	3,446
- Other chemicals	502	577
- Laboratory expenses	1,398	1,437
- Insurance	1,342	1,379
- Spare parts	8,919	26,399
- Ash Disposal(Landfill)	671	690
<b>Total Costs</b>	<b>55,542</b>	<b>74,894</b>
<b>Surplus</b>	<b>2,713</b>	<b>2,966</b>
Disposal fee covering operation cost (Baht/ton)	657.73	818.07
Number of day of operation(day)	320	320
Total Waste amount (Ton/day)	320.21	364.03
Total Waste loaded to incinerator(Ton/day)	253.33	262.85

**3. IMPROVEMENT OF PHUKET WASTE TO ENERGY**

To solve the persistent solid waste problem of Phuket, municipality has planned to invest new unit of incinerator as to increase disposal capacity. Another attempt to reduce waste load to the incinerator was the municipality then decided to award a concessionaire to private company for investment, building and operation a waste separation plant. But after operational failure and heavily financial loss for 5 years, the plant was

eventually suspended in 2006. Following to the master plan of Phuket waste mangement, in 2007 Department of Environment Quality Promotion collaborated with localities and NGOs lunched public participation campaigns to promote waste reduction and separation at sources. Organic waste separation model was initiated and implemented successfully in pilot communities such as Thepkrasatree municipality.[17] It was found that if organic waste could be removed from the main stream by 15-20% , then LHV of the mixed waste will lift up to the range of designed value, and maintain efficiency of combustion, reduce incomplete combustion emission and increase electricity generation yield. It emphasises the vital necessity of waste reduction and separation by waste generators at the generation points rather than being dependent on the waste separation plant.



**Fig. 5. Characteristic of Phuket waste to energy plant**

**Table 3: Adder rate for renewable energy [18]**

Fuel	Adder (Baht/kWh)	Period (yr)
1. Biomass	0.30	7
2. Biogas	0.30	7
3. Municipal solid waste		
- Anaerobic Digestion / Landfill gas	2.50	7
- Thermal Process	3.50	7
4. Wind	3.50	10
5. Small Hydro Power		
- installed capacity 50kW- <200kW	0.40	7
- installed capacity <50 kW	0.80	7
6. Solar Energy	8.00	10

**4. FEASIBILITY OF WASTE TO ENERGY**

Ministry of Energy refers to municipal solid waste as fuel sources of renewable energy and then in 2007, under the renewable energy promotion policy, the pricing subsidy was initiated to promote electricity generation from municipal waste. This provision is known as “Adder Provision” being an incentive additional rate on top of the normal buying rate of electricity as shown in

Table 3.

After the announcement in 2007, on the provision of “Adder,” overwhelming response has been received. The number of participating waste to energy generation has considerably increased to 14 projects by the end of 2010, making a total proposed sale of 13.45 MW.[19] 7 projects with a total proposed sale of 7.23 MW are electricity generation from landfill gas.

In case of Phuket incinerator, the incentive Adder could increase income from electricity sale and if the plant can simultaneously improve to produce more electricity as much as the original design, then the total income from electricity sale would be substantial to maintain the disposal fee at an affordable rate of 300 Baht/ton without any government subsidy. Fig.5 shows the characteristic of Phuket incinerator having 13% electricity conversion efficiency which seems to be lower side due to type of technology. Therefore if LHV of waste in Phuket remains less than 1,400 Kcal/kg, the additional rate Adder could rarely help the project to gain feasibility. The World Bank (1999) explained the correlation between quality of waste and investment cost of waste to energy plant. The actual investment cost for a waste to energy plant depends on a wide range of factors, especially the size (capacity) of the plant and the corresponding heating value of waste. Low heating value capacity plants are relatively more expensive than high heating value capacity plants in terms of investment cost per metric ton of capacity [20].

### 5. CONCLUSION

It is worthy to state that the main purpose of incineration is the treatment resulting in volume reduction and in rendering the waste harmless; the income from electricity sale depends on the heating value or energy content of waste and plant efficiency. A decade of Phuket incinerator as earlier described, heating value of waste can be improved by waste separation at source which has been internationally recognized as the priority of waste solution.

The master plan of Phuket waste management emphasizes waste reduction and separation as priority of waste solutions. With particular characteristic of waste in Thai society, thermal treatment process such as incinerator should not be selected as stand alone solution. It has to combine with any organic waste utilization or treatment process either aerobic composting or anaerobic digestion which could utilize or treat the major portion of waste. The combination of appropriate end of pipe technologies could be successful provided that the non-end of pipe solution such as waste separation at sources has to be implemented.

The success of public participation in waste management particularly food waste separation has given the valuable lessons to the province which could extend countrywide.

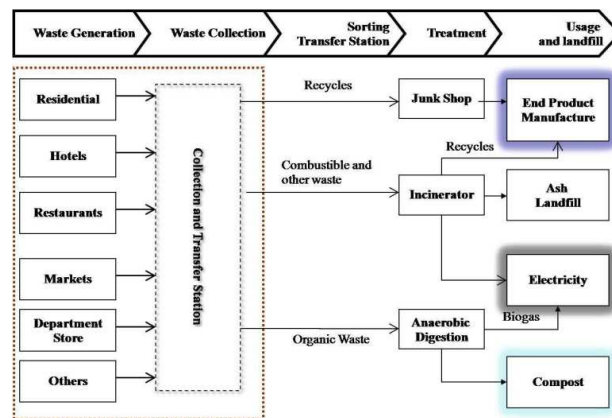


Fig. 6. Combination of technologies solution.

1) People can easily learn and realise the necessity of waste separation and are willing to contribute their effort to help locality in any waste activity, but in many cases, it is found that the barrier is the preparedness of locality in arrangement of proper collection and transportation especially for food waste, utilisation or treatment system of each type of separated waste.

2) Heating value quality of waste can be improved by reducing organic proportion in the mixed waste and the most efficient process is separation at sources.

3) With an integrated approach or combination of end of pipe technologies, the waste management will be successful.

4) Composting is not suitable for food waste especially in large amount, anaerobic digestion will be the most appropriate treatment for food waste.[21]

Finally, the Fig.6 concludes the lessons from a decade of Phuket incinerator. The optimal condition for establishment of waste to energy plants if locality has organized recycling based on waste separation at source and combination of technologies instead of single technology solution.

### ACKNOWLEDGMENT

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