The Cost-benefit Analysis of Waste Treatment by Incineration Method: Rajburana. Bangkok

By

Ms. Pattanee Komprasertphol

A Final Report of the Three - Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
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ABSTRACT

At present, the problem of waste disposal is spreading and getting more serious. In Thailand, Chiengmai is an especially the good example on the problem of waste disposal. In Lumphun the protests of local people to the construction of the incineration plant is another problem which occurs due to the NIMBY syndrome.

To avoid the NIMBY syndrome, and to avoid the protests to the construction of incineration plants, the idea of this report is highlight that everyone has to bear the burden about the waste that he disposes, so each Amphur should have an incineration plant in his area to eliminate his own waste. Incineration method is another alternative to propose to the local people. Amphur Rajburana is selected as the sample, with many reasons which, will be mentioned in the Chapter III.

This report will discuss the reason for using the incineration method, the available incineration technology, and the appropriateness of using the method. A case study in Amphur Rajburana in Bangkok Metropolitan area, will detail the cost and benefits that will pay and get in constructing the incineration plant.

From studies the cost-benefit, it shows that Amphur Rajburana should implement the incineration plant with 300 tons/day capacity with reasons that it can reduce the volume and weight approximately 70% of its original size. It is an advantage for the large city, which has limited space and help to reduce the problem of inadequate living place. Although the investment is quite high, when comparing with the benefit, it can generate more benefits than cost, which is shown in Chapter V.

ACKNOWLEDGEMENTS

I am indebted to the following people and organizations. Without them, this project would not have been possible.

I wish to express sincere gratitude to my advisor and co-advisor, A. Smith Tungkasmit and Dr. Chamnong Jungthirapanich. Their patient assistance, guidance, and constant encouragement have led me from the research inception to the research completion.

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Special appreciation is due to my family for their fervent and continuous encouragement. Above all, I am forever grateful to my parents whose willingness to invest in my future has enabled me to achieve my educational goal.

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I. INTRODUCTION

1.1 General

At present, the problem of waste disposal has been spreading and getting more serious, especially in Thailand, which has shown remarkable economic growth. As a result of recent industrialization and high population growth rate, the quantity of solid waste is increasing year by year. The counter measures for safety treatment and efficient utilization of the solid waste have become a matter of urgent necessity

Waste is the refuse from the production process of consumption, which needs to be eliminated in the right way. With good measurement will have the cast; with classifying before throwing away, or recycling will reduce the volume of waste. And with classification if combustible composition and incombustible composition of waste will help to select the appropriate method in treating the waste, which are incineration, composting, and sanitary landfill.

The waste treatment by incineration can generate the heat and electricity, which provide many benefits to the society and environment. Furthermore, with the limitation of land space for landfill, environmental regulation restriction, incineration technology, and the energy recovery (byproduct) has low cost for waste elimination. Moreover, it can help to reduce both the volume and weight of waste to a small volume of ash. This ftethod is popular in Japan, Taiwan, Singapore, Switzerland, England, Sweden, Germany, and France.

This report will present about waste treatment method, incineration technology„ advantages and disadvantages of incineration method, waste information, background of study, the cost-benefit analysis, and conclusion and recommendations. And the next topic is the objectives of this report; it will present the reason why the incineration topic is studied.

1.2 Objectives

The objectives of this report are

(1) To study the technologies of incineration in order to present the working system of the incineration plant briefly.

(2) To study and estimate the cost and benefits of treating waste by incineration method to evaluate the possibility of this project.

(3) To study the byproducts benefit which is the electricity generation from treating the waste by incineration.

These objectives will help to present whether the incineration is an interesting method in treating waste in Bangkok and is feasible to invest or not. The next topic is the scopes and limitations in preparing this report.

1.3 Scopes and Limitations

Efforts to build new solid waste management facilities have unquestionably led to political conflict and stalemate in many countries. To some, this is the result of the not-in-my-backyard (NIMBY) syndrome, used to invoke images of misinformed citizens egged on by "environmental evangelists." To others, NIMBY is 'the incinerator vendors' term for democracy."' Because that citizens who are offered poor information and limited choices feel compelled to act in opposition, especially given the history of glaring environmental disasters in waste management, such as the local people in Lumphun who derived the environmental impact from the waste of Lumphun Industry.

Richard A Denison and John Ruston., Environmental Defense Fund, <u>Recycling and incineration: Evaluating the choice</u>, Island Press, page 23

When there was a project about the setting the incineration plant in Lumphun, most of the local people protests this project.

To avoid the problem of NIMBY syndrome this report, it will begin with the idea that each Amphur has its own responsibility to reduce and eliminate its own waste. So the scope of this study is limited to the municipality of Amphur Rajburana, which is the Amphur which has just been assigned, from the Bangkok Metropolitan Administration Department of Public Cleansing, to publicize to the local people to classify the type of waste before disposal. For the staff, they are educated and trained in classifying the type of waste before taking waste to the garbage trucks treating waste_

With inexperience in Engineering background, this report may have to copy some texts and some reports in order to make this report fulfill its aim.

The next chapter is the Literature Review, which presents the information about the waste treatment method, waste treatment by incineration, the location of solid waste incineration facilities, and the waste information.

LITERATURE REVIEW

This chapter will present about the waste treatment method in Bangkok, waste treatment by incineration method, location of solid waste incineration facilities, and information about waste. The waste treatment by incineration method includes type of incinerators, process of waste treatment by incineration, environment impact and the advantage and disadvantage of waste incineration. This information is included in this chapter because it will help to support the decision making in selecting the method of eliminating waste.

2.1 The Waste Treatment Method

Waste, which is the refuse from production and consumption needs to be eliminated in appropriate ways to save costs and protect the environment. Waste treatment can be grouped into 3 categories, which are Composting, Sanitary Landfill, and Incineration.

Composting — is the process, which naturally occurs and is carried out by microorganisms. They will spontaneously grow in any mixed natural organic waste if it is kept moist and aerated. The growth of these organisms, which initially are predominantly bacteria, liberates heat, CO2 and water vapour. If heat is generated faster than it can escape, the temperature will rise, killing the heat-sensitive organisms and facilitating the growth of heat-tolerant bacteria. In the first stage, mesophilic bacteria as well as actinomycetes, yeast and other fungi break down fats, proteins and carbohydrates. Protozoa prey on the bacteria and fungi. As the temperature reaches the range of 40-50°, nearly all the organisms that initiated the composting action are killed and their place is taken by a more limited series of thermophilic bacteria which can grow and produce heat up to a temperature of 70°C. In that part of the compost that reaches

60-70°C, essentially all pathogenic organisms, except for a few spores, are killed in a few hours. When the thermophilic bacteria have exhausted the food available to them, they stop producing heat and the compost cools off. In the cooling compost, a new series of food, including dead bacteria, give the compost its final properties. The three stages of composting may be referred to as the initial end product of composting is a mass of organic material composed of indigestible residues closely resembling the humus that is made naturally processes. Ammonia, which is toxic to germinating seeds, is produced in the first two stages and is removed in the curing stage. It is a more costly method designed to transform previously sorted refuse, by fermentation into a soil amelioration factor for agricultural use. The result is a product containing too much plastic material and miscellaneous scrap for it to offer good value and, in any event, waste recovery is only partial.

Sanitary Landfill — is a method, which involves the collection of waste into one area and uses machines to level off and crush the waste over the land area. The crushed waste will be tightened covered up by ground and another layer of waste is poured on top and crushed layer by layer. This process helps to reduce the problem of bad odor, insects and rain, and other irritating situations, which might be caused by waste. The organic chemicals that existed in the waste will be disintegrated naturally by microbes. This process is an anaerobic decomposition causing waste to decompose producing methane gas and polluted water in the land. The process of sanitary landfill needs measures to protect or treat polluted water and ventilate the poisonous gas out of the area. The land that is use for landfill needs to be proved and claimed suitable.

Incineration — is the process of reducing combustible waste to an inert residue by high-temperature burning. It can be applied to a wide range of waste: solid sludge, liquid waste or gaseous waste. Some plants can process different kinds of waste simultaneously. It is often an appropriate treatment and disposal process in areas of high population density, where land for disposal of untreated waste may be unavailable, but it can present several economic, ecological and technical disadvantages. These include high construction costs, high operating and maintenance costs, the need for highly skilled personnel to operate and maintain the plant among others.

2.2 **The Waste Treatment by Incineration**

2.2.1 Introduction

Table 2.1 shows the estimated generation of waste in Bangkok will reach 18,750 tons per day by the year 2015. The annual report issued in 1998 shows the amount of waste collected by the authority reached 8,591,720 tons in 1998. Waste which generates stench day and night is piling up in places such as backyards and alleys, although places in sight, such as main streets and public parks, are clean. In addition to odor, flies, rats, and the like are apt to disperse disease germs.

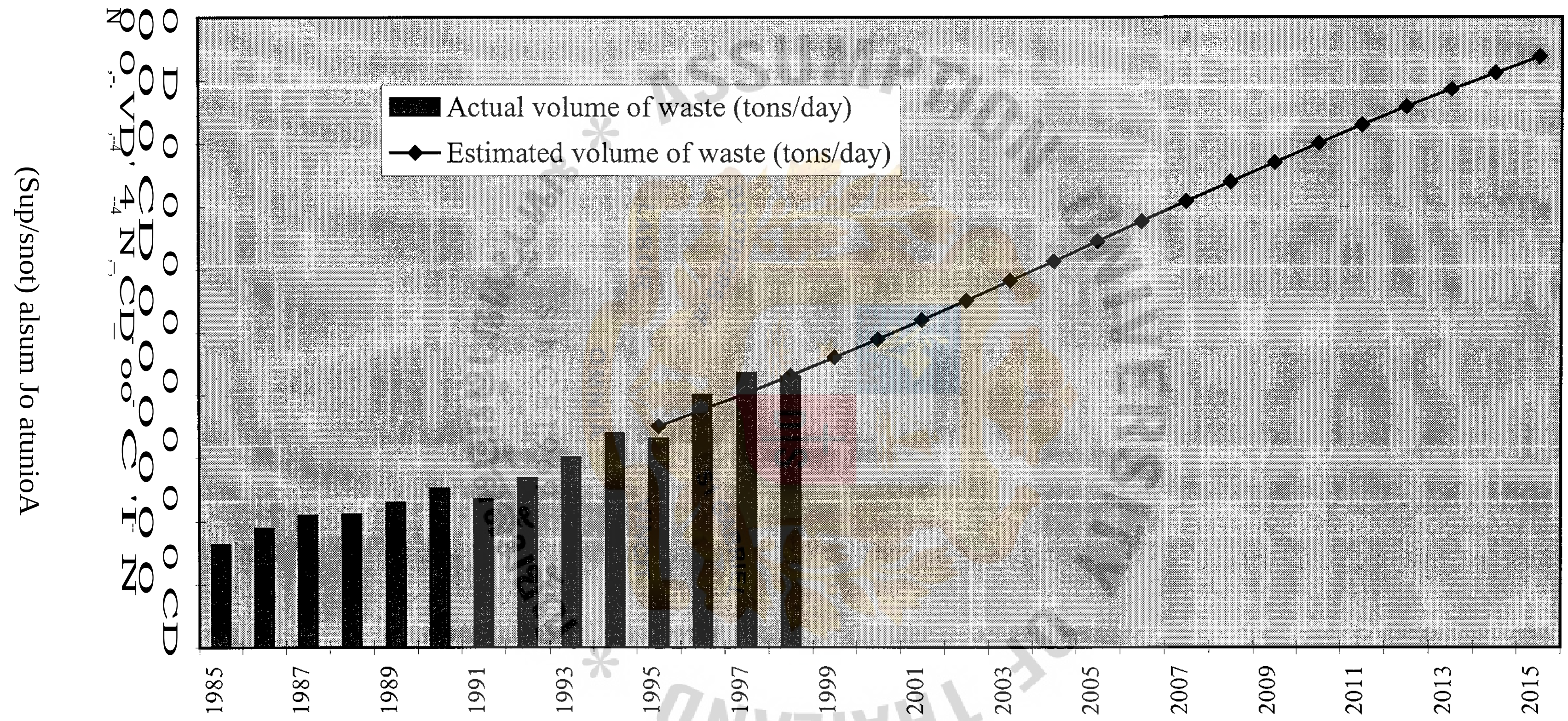
It is very difficult to properly treat such a large amount of waste by individual or private companies respectively. Some people burn waste uncollected in their backyard. However, serious air contamination will arise if many people burn waste in this manner. As the incineration is an approach, which has a high performance pollution control system, it is suggested as an appropriate method due to the shortage of sites for landfill. The following describes the effectiveness of incineration, which could result in the notable reduction and high resource recovery.

Table 2.1. The Actual Volume of Waste Generated from 1985 to 1998 and the Estimated Volume of Waste Generated from 1995 to 2015.

Year	Actual volume of waste (tons/day)	Estimated volume of waste (tons/day)
1985	3,260.22	
1986	3,782.64	
1987	4,190.09	
1988	4,224.85	
1989	4,597.70	
1990	5,044.80	
1991	4,706.03	
1992	5,372.17	
1993	6,015.65	
1994	6,798.28	
1995	6,633.71	7,020.00
1996	8,000.86	7,540.00
1997	8,703.25	8,070.00
1998	8,591.72	8,630.00
1999		9,210.00
2000		9,800.00
2001		10,410.00
2002		11,030.00
2003		11,650.00
2004		12,280.00
2005		12,920.00
2006		13,550.00
2007		14,180.00
2008		14,800.00
2009		15,420.00
2010		16,020.00
2011		16,600.00
2012		17,170.00
2013		17,720.00
2014		18,250.00
2015		18,750.00

Note : The estimated volume of waste is calculated by Mr.Takashi Sasaki by JICA

Source: The Bangkok Metropolitan Admininstration



The Actual Volume of Waste from 1985 to 1998 and the Estimated Volume of Waste Generated from 1999 — 2015.

(1) Solid Waste Volume Reduction as a Result of Incineration

The primary advantage of incineration as a technique for managing solid waste is its ability to reduce the volume requiring disposal. Efficient combustion can accomplish up to an order-of magnitude reduction in the volume of material introduced into a incinerator.

The actual volume reduction varies tremendously in practice. For efficient mass-burn system, reasonable rule of thumb estimates are 80-90% by volume, relative to the amount of waste received uncompacted. While the reduction in weight is smaller, which is in range of 65-75%, weight reduction is often relevant. Degree of volume reduction is best evaluatd by comparing the physical volume of the incoming waste against the physical volume of ash residue.

(2) Recycling Related to Incineration

The municipal waste contains many things which are made of petroleum based products, so the heat value is sufficient to be used as fuel. It reduces the running cost of plants by using the power for self-consumption. The surplus power and hot water can be sold to an electric company and/or a heat supply company which can bring additional revenue to the plant. Energy recovery through the means of incineration can be more advantageous than material recovery, such as; old paper recycling and plastic recycling in view of cost performance. Although each incineration plants capacity is small , the total consumption of fossil fuel can be reduced as there is less imported fuel, the balance of payment will be better, the electricity company's loss from exchanging currencies is less. The air pollution which causes global warming can be reduced if the fossil fuel can be reduced.

(3) Utilization of surplus heat at incineration plant

Figure 2.2 shows the Effective Utilization of Heat Energy. Heat generated by incineration plant is used in the following manner:

(a) Uses within the incineration plant

Some amount of steam is used for driving devices, such as combustion air heaters, soot blowers, air conditioners, etc. inside the plant. About 30% of the steam produced by the boiler is consumed or such inside use.

(b) Heat supply to public facilities nearby the plant

Heat is provided free of charge to public facilities, such as gyms, warm water swimming pools, community centers, recreational centers for the aged, green house at botanical garden.

(c) Heat supply to district heating and cooling service businesses

Heat is supplied for a price to provide a heat source for area-wide air conditioning.

(d) Power generation by steam turbines

Power is produced by steam turbines to supply electricity within the plants and to sell excess power to EGAT. The power used inside the plant comes to about one half of the total power output, that is 90% of all power used at the plants.

BOILER

This equipment recovers the waste heat produced from combustion of refuse as well as enabling harmful gases to easily be treated.

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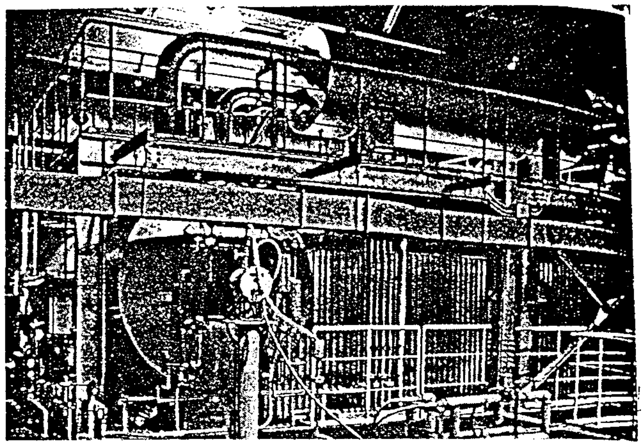

TURBINE GENERATOR

The steam resulting from cooling combustion gas in the waste heat recovery boiler drives a steam turbine generator to generate electric power of maximum 11,000 kW which mainly is used for plant operation and other surplus for sale.

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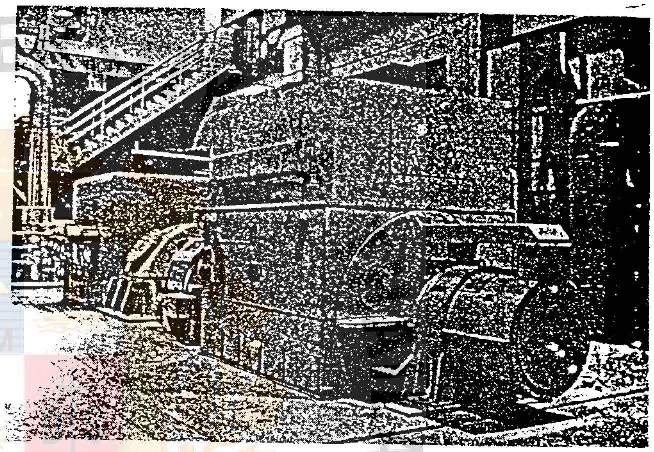

SURPLUS HEAT UTILIZATION SYSTEM

The surplus heat is used to provide air-conditioning and hot water services with the neighboring facilities and pool.

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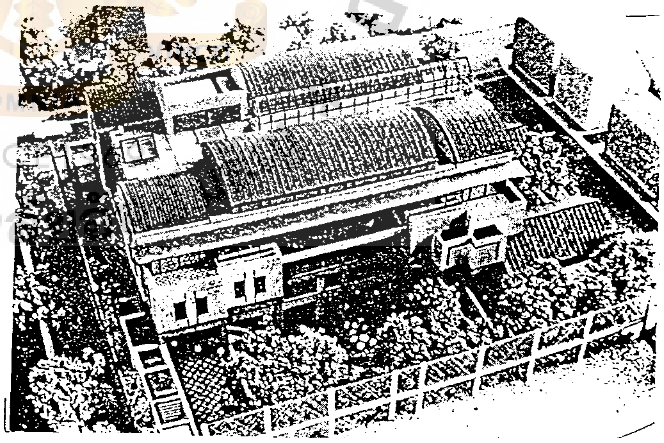

Figure 2.2. The Effective Utilization of Heat Energy.

2.2.2 Types of Incinerator

There are several types of incinerators. Current solid waste incinerators are mainly categorized into 3 types by their structure, that is; stoker type incinerator, fluidized-bed incinerator, and rotary grate incinerator. However as there are few examples of rotary kiln incinerator for municipal solid waste, this paper will mention only two types of incinerator.

(1) Stoker Type Incinerator

The basic functions of stoker are maintenance of continuous stable combustion, smooth separation and discharge of riddling ash, consistent supply of combustion air over the stoker surface, excellent resistance against high temperature and corrosion, simple inspection maintenance, and so forth. The Figure 2.3 shows the Mechanical Stoker Incinerator.

In order to meet the requirements of these basic functions, respective manufacturer have implemented repeated testing with experimental systems. They have developed their own products based on empirical engineering and verification of data obtained from models installed in the past. It is known the waste characteristics varies widely country by country and region by region, the relax to provide optimum combustion conditions, a stoker must be designed and manufactured with abundant experience and should be selected depending on whether such specific requirements are met or not.

(2) Fluidized-Bed Incinerator

Other than the stoker type incinerator, there is another system to incinerate refuse, called a fluidized bed type, the features of which vary widely depending on respective manufacturers although the principle and functions are nearly same.

With this type of incinerator, a series of combustion takes place within a fluid media (sand). Over the surface and in the secondary combustion chamber above it, the driving power to constitute the fluidized bed is provided by combustion air which is supplied through dispersion plates disposed at the bottom of the bed. Since the amount of air can be controlled within a range of air tower velocity 2 to 3 m/sec., the maximum and minimum amounts of air have some limitation. Refuse is mixed, stirred and incinerated by the supply of air.

Based on the principle, actual equipment is designed and manufactured giving consideration to considering such factors as the refuse feeder type the auxiliary burner location and relative combination with boiler, and the ash discharge method. The location bed type incinerator with which these factors are studied, tested, constructed and operated in accordance with accumulated experience is shown in a manner to clarify the structure to combine a boiler. Boiler structure is designed normally based on the same concept as a stoker type furnace except that a provision to cope with a higher dust concentration is incorporated in this type of furnace.

Figures 2.4 and 2.5 show the Fluidized Bed Incinerator and the working of Fluidized Bed Incinerator. And Figure 2.6 shows the example of Internally Circulating Fluidized Bed Boiler (ICFB).

To select the type of incinerator required it is necessary to compare the characteristics of both types in order to get the lower cost and full capacity, suitable for the waste in Rajburana. Table 2.2 shows the comparative characteristics between the Stoker Type Incinerator and the Fluidized Bed Incinerator.

Table 2.2. The Comparative Characteristic of Stoker Type Incinerator and Fluidized Bed Incinerator.

Item	Stoker Incinerator	Fluidized Bed Incinerator
• **Structure**	• The hearth consists of movable grates • Longitudinal structure	• The hearth consists of sand layer • Furnace structure is simple • No moving part inside • Smaller size structure
• **Furnace Load**	• 200 —250 kg./mh.	• 450 - 500 kg./mh.
• **Combustion Residue**	• The residues need to be treated carefully because it can be the cause of secondary pollution	• The residue is dry ash and no further pollution
• **Incineration capacity**	600 tons/day	• 150 — 350 tons/day
• **combustible speed**	• slow and steadily • waste burns on the grate for about 2 hours	• Rapid • Combustion is complete in a few minutes
• **Max heat value**	• About 3,500 kcal/kg.	• About 5,000 kcal/kg.
• **Moisture combustion**	• Burns well, but it needs more time	• Burns well
• **Plastics combustion**	• The strong fire from plastics is apt to damage the furnace wall. • It can incinerate the plastic composition not exceeding 35%	• The fluidized sand absorbs and spreads the heat, so high calorific value plastics burn well without damaging furnace. • It can incinerate the plastic composition not exceeding 50%
• **Ignition Loss**	• 7% for 100-200 tons/day • 5% for more than 200 tons/day	• 0.5% of waste

Table 2.2. The Comparative Characteristic of Stoker Type Incinerator and Fluidized Bed Incinerator. (Continued)

Item	Stoker Incinerator	Fluidized Bed Incinerator
• **Odor**	• has odor	• No odor
• **Heat Recovery**	• Steam generation is comparatively stable • Stable electric generation is possible	• Stable steam generation is possible by means of controllers
• **Residue Percentage (ash/total waste before incinerate)**	• **7 -** 30% (average 16.1%)	• 3 - 17% (average 7.7%)
• **Weight (ash/total waste before incinerate)**	• 16.1 tons out of 100 tons	• 7.7 tons out of 100 tons or 7.7%
• **Bulk Density**	• 0.7-0.9	• 1.0 — 1.3
• **Pollution Control** • **Dust** • **No„** • **Co** • **Hcl**	• Safe according to law • Fly ash volume is small • 80-150 ppm. • 50-1000 ppm. • **Depend** on waste quality	• Safe according to law • Fly ash volume is large • 80-150 ppm. • 50-1000 ppm. • Depends on waste quality
• **Manpower Required**	• 4-6 person/ shift	• 4-6 person/ shift
• **Reliability & Consistency**	• Rliable • Quite consistent	• Quite reliable • Consistent
• **Fuel Required** • **Electricity** • **Fossil oil** • **Water**	• **80-120 Kw/1** ton of waste - 2-31 tons/ 1 ton of waste • 1-2 $M^2/_1$ ton of waste	• 80-130 Kw/1 ton of waste • 1-21 tons/1 ton of waste • 1-2 $M^2/_1$ ton of waste
• **Pre-treatment Equipment**	• **Pre-treatment equipment is** not required for ordinary waste	• **Some** conventional types requires pre-treatment facility.
• **Land for Construction**	• Required long but narrow	• Required small size
• **Heat Value**	• **About 3,500 kcal./kg**	• **About 5,000 kcal./kg**

Table 2.2. The Compar ative Characteristic of Stoker Type Incinerator and Fluidized Bed Incinerator. (Continued)

Item	Stoker Incinerator	Fluidized Bed Incinerator
• **Maintenance**	• Parts of grate shall be replaced periodically. The maintenance costs are more than Fluidized type	• Air dispersion nozzle shall be replaced periodically; it does not cost so much.
• **Maintenance Cost**	• Quite high	• Low
▪ **Construction Cost**	• Same as Fluidized type	• Same as Stoker type
▪ **Operation**	• It takes about 20 hours to start and/or stop the plant. • Automatic combustion control systems have been established	• The start and stop of the plant is quicker than stoker type • Automatic combustion control systems have been established

Source: Bangkok Metropolitan Administration

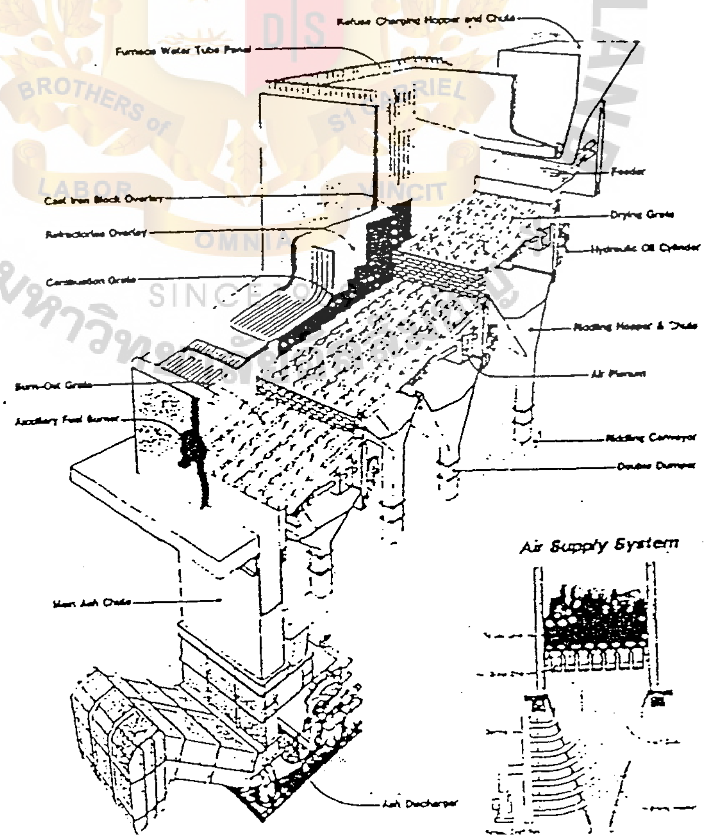

Figure 2.3. The Mechanical Stoker Incinerator.

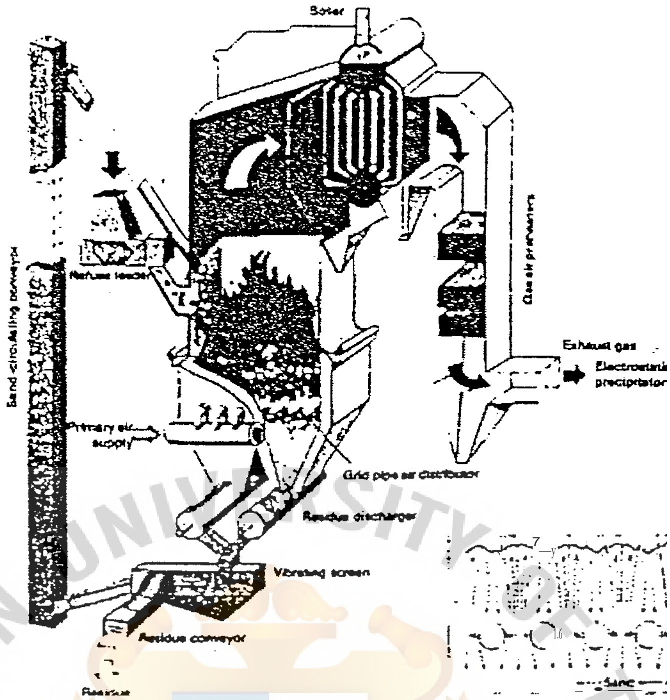

Figure 2.4. The Fluidized Bed Incinerator.

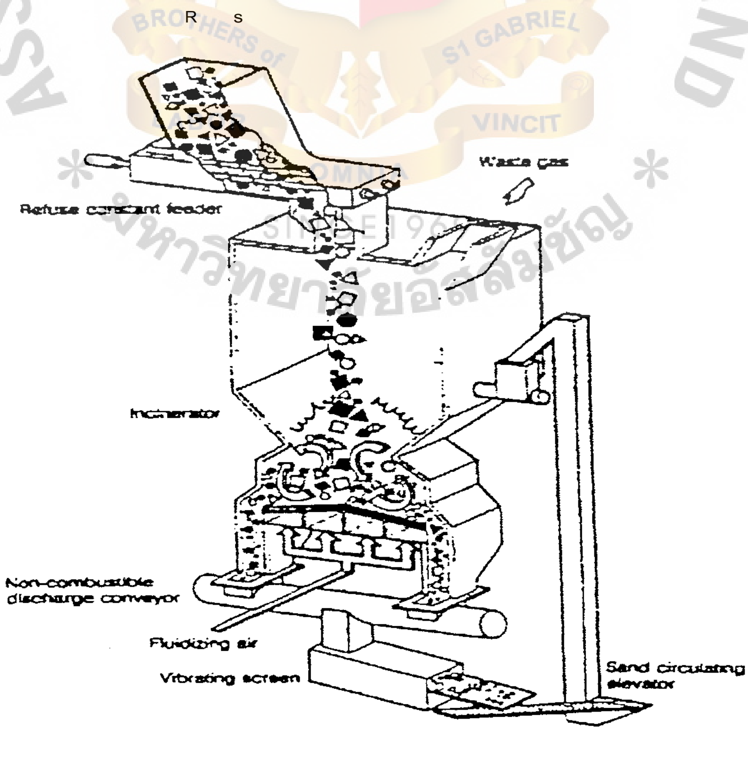

Figure 2.5. The Working System of Fluidized Bed Incinerator.

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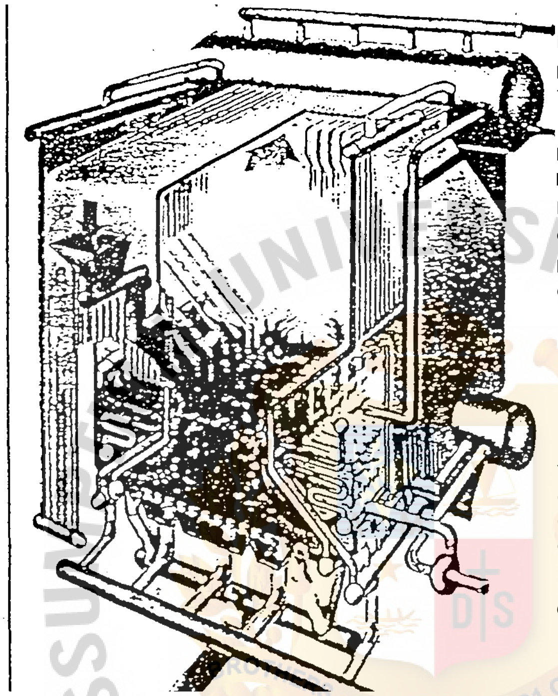
4NTERNALLY **CIRCULATING FLUIDIZED BED BOILER MB**



Ebara has developed the Internally Circulating Fluidized Bed Boiler (ICFB), which supplies stable and inexpensive energy, as an industrial use boiler and public utility facility.

The ICFB provides a variety o(advantages, including table combustion and low rates of environmental pollution. It can use many different types of fuels. Wg believe that the ICFB will contribute greatly to Industry and to society as an energy plant for converting Industrial waste resulting from production processes into the energy needed to operate industrial plants.

FUEL SUPPLY

Various types of wastes can be used as fuel or -in joint combustion with coal. Even low-grade coals *are* highly combusted and feed is simple. Post-commissioning changes *in* source fuel can be easily accommodated.

OPERATION

Operation can be intermittent. Erosion of heat exchange woes is minimized. Non-combustibles are easily extracted in a clean dry form.

ENERGY PRODUCTION

Steam load can be varied without difficulty. Heat extraction is efficient *and* electricity generation can be matcned to need

The outstanding performance of the ICFB in the combustion of both coal and wastes is the outcome of the successful combination of three types of circulation.

POLUTION CONTROL

Formation of nitrogen oxides is minimized. In-bed Cesuf furization is consistenly high.

1. Circulation of the sand between moving and fluidized parts of the combustion cell.
2. Circulation of sand to and from the combustion cell to the heat exchange cells.
3. Circulation of unburnt char from the exhaust gas cyclone back to the sand bed.

Any non-combustibles included in the fuel pass to the outlets on either side of the bed and are discharged in a clean dry form with some sand which is separated and returned to the bed.

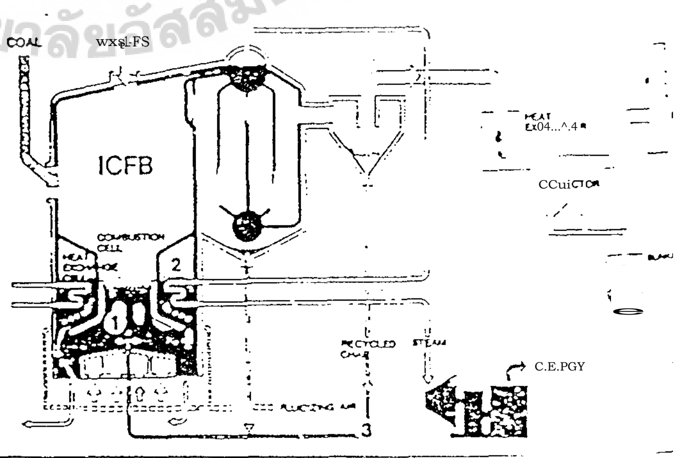


Figure 2.6. The Example of Internally Circulating Fluidized Bed Boiler (ICFB)

From the aforementioned data about the type and capacity of incinerators, the Fluidized Bed Incinerator with full continuous incineration plant is recommended due to the volume of Rajuburana waste, which will be presented in the next chapter. It is easy to start and stop incinerating as the heat of the sand is maintained for a while in the incinerator and it can generate higher heat than the Stoker type. Although its frill capacity is lower than the Stoker, the plastic composition can be burned in Fluidized Bed Incinerator more than Mechanical Stoker Incinerator around to 15%.

2.2.3 The Process of Waste Treatment by Incineration

The waste treatment by • incineration is an effective way to reduce the volume of the waste to 80-90% by using the main qualifications of waste in burning in incinerator. It needs the appropriate factor in burning, such as air, fuel, temperature, pressure, capacity and type of incinerator. From burning, it makes the gas, evaporator, and ash. The temperature in final burning in incinerator is within the range between 850 – 1200°C. The process of waste treatment by incineration can be divided into 6 steps, which are preparation process, incineration process, residue handling process, flue gas cooling process, flue gas treating process, and waste water treating process. The detail of each process will follow.

Figure 2.6 shows the basic diagram of waste incineration plant in order to understand more about the incineration process and figure 2.7 shows the facility of waste-to-energy plant.

(1) Preparation Process

After the trucks collect the waste from the sources, the truck will dump the waste into the dumping site for screening or sorting the physical composition of the waste. This is because some elements can be recyclee or reused, some can't be burned, some are toxic when burning, and some generate very low heat value. So it is needed to screen the composition of waste before incineration. This can be manual sorting of value products on platform by unloading of garbage trucks or automatic sorting of non-combustible solid matters.

After sorting the composition of waste, these will be kept in the first storage pit before sending to incinerator.

(2) Pressing Process

The waste is pressed in order to extract vegetable organic wet matters and it is stored in biodisgestor hermetical tanks (without any smell) till the end of fermentation and transformation in Potting Soil of fertilizers. The dry and solid matters are grind, homogenized and transported to the main storage pit in the incineration plant.

(3) Incineration Process

The waste is transported from the main storage pit to the incinerator, which needs to be run all the time, the two or three incineration lines working in parallel are required. At the bottom of the furnace, the movable grate will extract the ashes and slags.

The flux of hot gas coming out from the furnace pass through high performance boilers for production of high steam which is destined for electricity production. This section will be explained in the topic of generating electricity from waste.

(4) The flue gas cooling process

The filters networks, installed after the boilers with coolers, flagging system will purify the flux of gas and smoke allowing the exhaust by the stack of one non-pollutant rejection.

(5) The Flue gas treating process

After they become cold, ashes, slags and flying ashes are neutralized, solidified by agglomeration with resins, enveloped and stabilized under the form of pallets of different granulation for underground preparation, drainage beds, or production of breeze-blocks or pedestrian ways edges.

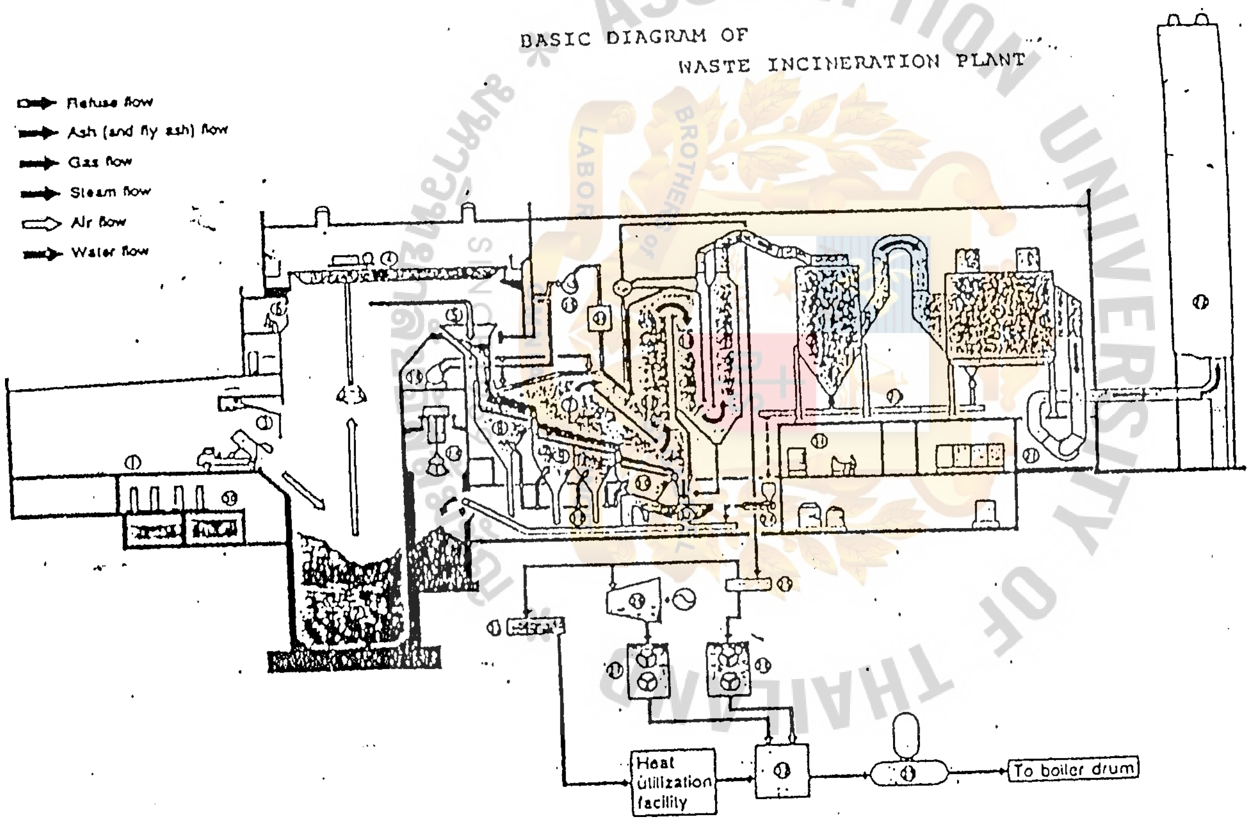
With the introduction of this process, the quantity of matters to discharge in landfill could not exceed 2% of the quantity of waste collected.

(6) Waste water-treating process

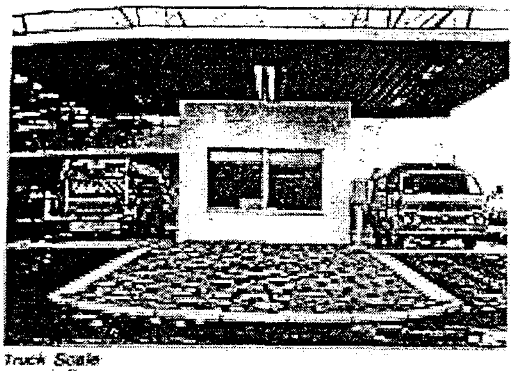
The wastewater from the incineration plant is occurred from cleaning the waste and plant, residue handling process, flue gas cooling process, etc. The wastewater treatment in incineration plant is

Recycling water — It can recycle to use for cooling down the flue gas, or it can be treated by physical and chemical way, which are neutralization and coagulation.

Releasing the cleaned water — It needs to use the coagulation method and biology, such as activated sludge process, or catalytic oxidation, or filtration.



bA a) N The Basic Diagram of Waste Incineration Plant.



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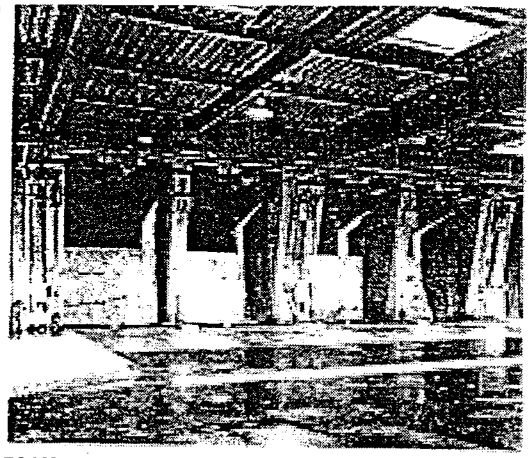

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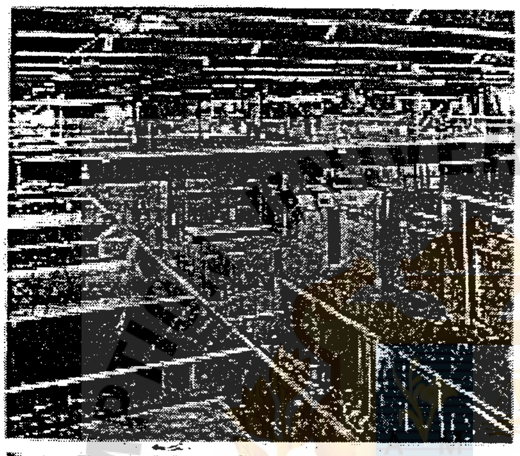

Tipping Floor and Bunker Doors
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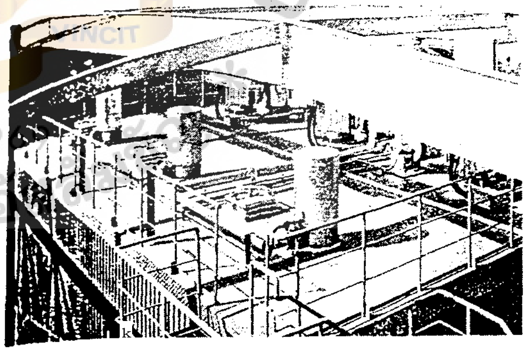
Incinerator



Bectrostatic Precipitator
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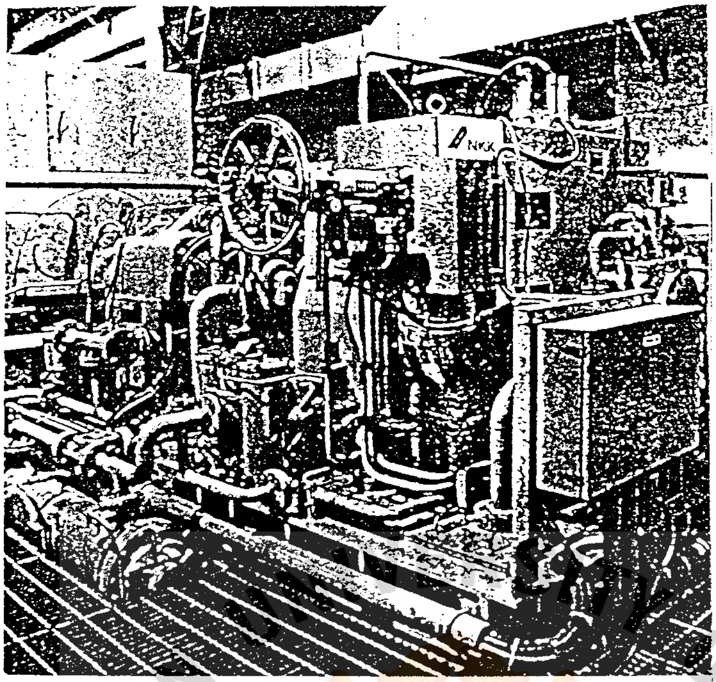
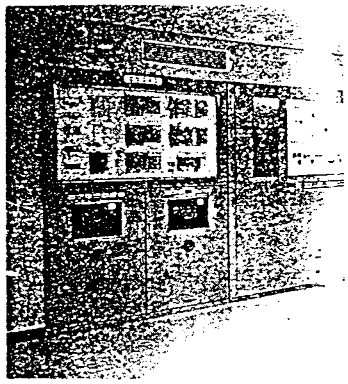
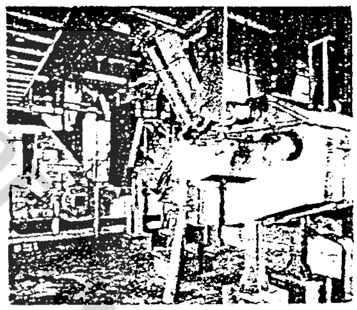
Figure 2.8. The Facility of Waste-to-energy Plant.



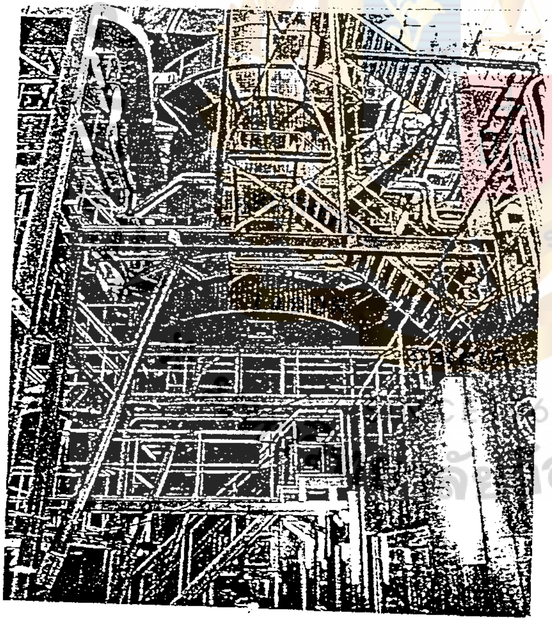
NKK Steam Turbine Generator
(t07 DJ6-1 fie16li tri)



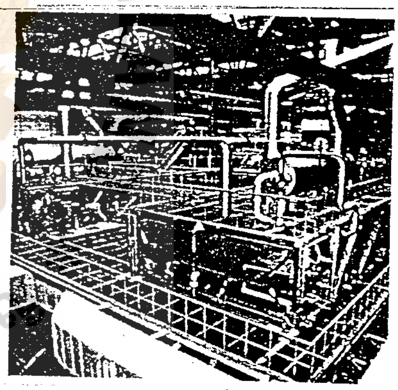
Control Room
(ห้องควบคุม)



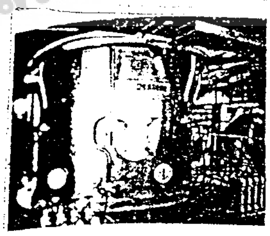
Ash Pusher
(ı fi7a•.1 I'; Ull I r'ว)



NKK-LIMAR (Rue Gas Scrubber)
(vinrniti ñinitisr7s)

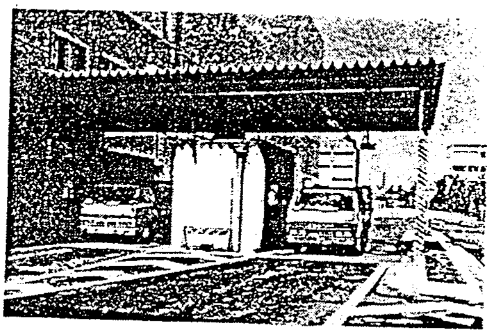


Waste Heat Boiler (NKK Comer Tube Type) (หม้อต้มน้ำ)



Gas Cooling by Water Injection
(nlnîibrut7frill1449,1 Tem'7 74I47)

Figure 2.8. The Facility of Waste-to-energy Plant. (Continued)



Truck scale
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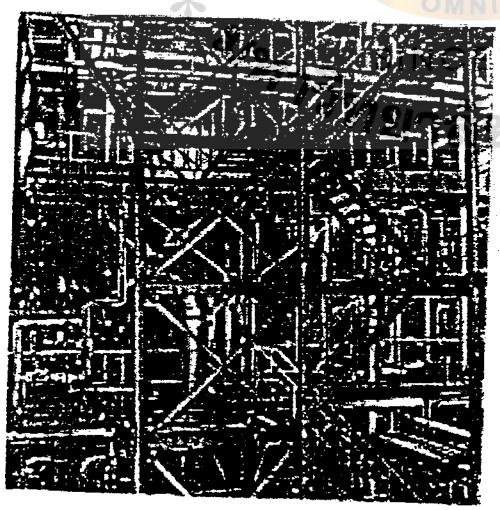

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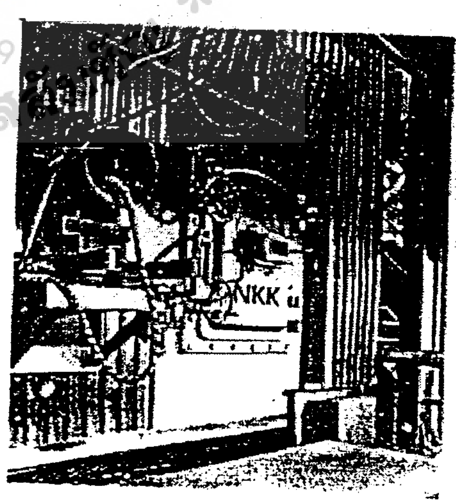

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Figure 2.8. The Facility of Waste-to-energy Plant. (Continued)

2.2.4 Environmental Impacts due to Refuse Incineration

It is primary pollution for the refuse itself. And after incinerating the refuse, the secondary pollution will follow. The first important impact is the exhaust gas from incineration plant. It will affect to the environment and the nearby people. The second possible pollution is noise, if the incineration plant is set up near the community, it can cause people deaf or hard of hearing. The third impact is wastewater. This may not affect to nearby community much if there are wastewater treatment in the plant and checking the composition of the wastewater before releasing to outside. And the last impact is the bad odor, but installing the air curtain at the entrance and exit of the plant can relieve it.

The degree of pollution is strong or not, it depends on the geographical area of the plant location and the management of the authorized person and responsibility of the controller.

2.2.5 The Advantages and Disadvantages of Eliminating Refuse by the Incineration Plant

The Advantages of the incineration plant are:

(1) The volume and weight of the waste is reduced to a fraction of its original size.

(2) Waste reduction is immediate; it does not require long-term residence in a biological treatment pond or other land disposal system.

(3) Waste can be incinerated on-site, without being transported to a distant area.

(4) Incineration requires a relatively small disposal area, not the acres and acres needed for lagoons or other land disposal methods.

(5) The ash residue may be subject to declassification as hazardous waste. In this case, incineration becomes essentially a final disposal method as well as treatment method for waste.

(6) Incineration is easily terminated. The cessation of incineration activity will remove any liability for the generator or the operator. With land burial, the liabilities are indefinite and uncertain.

(7) Through heat recovery techniques, the cost of operation can be reduced or offset by the use or sale of energy.

Although incineration method is becoming attractive as a waste disposal option, it is not universally applicable to waste disposal. The disadvantages of the incineration plant are:

(1) Some materials, such as highly aqueous waste or non-combustible soils, are not incineration.

(2) The control of metals from the incineration process may be difficult for inorganic wastes with a heavy-metals content.

(3) Incineration represents a high capital cost

(4) Skilled operators are required.

(5) Supplemental fuel is required to bring up an incinerator to operating temperature and, with some materials, to maintain combustion temperatures.

2.3 Location of Solid Waste Incineration Facilities

In the past, solid waste treatment facilities had often been the causes of environmental deterioration of their surroundings effected on by many sources, which caused air pollution, rank odor, and water contamination, and they had in so many cases stimulated antipathy of nearby against the facilities.

Before selecting the location of an incineration plant, there are several factors to be determined in compliance with the solid waste management master plan. There are waste amount to be coped with by the plant, collection areas from where wastes will be carried into the plant and the waste composition and properties. Upon these factors appropriate size of the plant and specifications of the facilities can be determined, and plant location will be selected taking into account waste collection and haulage efficiency, terrain of the site and the land acquirability.

In planning solid waste management facility where the area is vast and waste amount is tremendous, it is unavoidable process to ask the residents for understanding and cooperation, and consult and coordinate with the concerned organizations on conformity with the comprehensive city plan and environmental conservative plan and have their consent far in advance of setting about the solid waste management facility plan.

In selection of the site, the first priority will preferable by given to higher transport efficiency. The other conditions are as follows:

(1) Simple in shape and flat on surface as possible

(2) Its surroundings are less vulnerable to the influence

(3) Adjacent to main trunk road

(4) Electricity and water are supplied and waste water dischargable

(5) Sufficient area of land will hopefully be acquired taking into account construction of additional facilities to counter waste increase in the future or to upgrade anti-pollution facilities, and preparing for reconstruction of the main plant.

2.4 The Waste Information

2.4.1 The Source of Waste

Major source of waste in different area of Thailand may be classified as follows:

(1) Domestic source — It includes family dwelling, duplex, multifamily dwelling low, medium, and high-rise apartments. Household waste is the chief constituent of wastes.

(2) Commercial source — It includes stores, restaurants, markets, office complex and others. The wastes generated from commercial sources consist of many variety of refuse.

(3) Institutional source — It includes universities, schools, hospitals, government office and others. The institutional solid wastes generally contain a large proportion of paper and other light materials, that could be separated easily for recycling or combusting to recover heat energy.

(4) Street sweeping source — It includes streets, alleys, parks, highways and others. The type of wastes consists of rubbish and special wastes.

2.4.2 Types of Waste

Types of solid waste may be classified as follows

(1) Residential and commercial wastes - Residential and commercial wastes consist of the combustible and non-combustible solid wastes. Typically the organic fraction consists material such as food waste, garbage, paper, card board, plastic, textiles, rubber, leather, wood and yard wastes. The non-combustible fraction consists of items such as glass, crockery, tin cans, aluminum, ferrous metals, and dirt. If the waste components are not separated when discarded, then the mixture of these wastes is also know as commingle residential and commercial wastes

(2) Institutional wastes - Institutional sources of waste include government center, universities, schools, prisons, and hospitals. Excluding manufacturing waste from prisons and medical wastes from hospital, the wastes generated at these facilities are quite similar to commingled wastes

(3) Construction and demolition wastes - Construction wastes are wastes from construction, remodelling, and repairing of individual residences, commercial buildings, and other structures. The quantities produced are difficult to estimate. The composition is variable, but it may include dirt, stones, concrete, bricks, plaster, lumber, shingles and plumbing, heating and electrical parts. Demolition wastes are wastes from razed building, broken-out streets, sidewalks, bridges and other structures. The composition of demolition wastes is similar to construction wastes, but it may include broken glass, plastics, and reinforcing steel.

(4) Municipal services wastes - Municipal services wastes, resulting from the operation and maintenance of municipal facilities and the provision of other municipal services, include street sweeping, road side litter, waste from municipal litter containers, landscape and tree trimmings, dead animals and abandoned vehicles.

(5) Treatment plant wastes and other services - Treatment plant wastes are solid and semi-solid wastes from water, wastewater, and industrial waste treatment facilities. The specific characteristics of these materials vary, depending on the nature of the treatment process. Wastewater treatment plant sludge is commonly co-disposed with wastes in municipal landfills. Ashes and residues are materials remaining from the combustion of wood,

coal, coke, and other combustible wastes. These residues are normally composed of fine, powdery materials. Glass, crockery, and various metals are also found in the residue from municipal incinerators.

(6) Industrial Solid waste excluding process wastes - These are all wastes, which are generated as industrial sites, except industrial process wastes, and any hazardous wastes. The specific components of these wastes vary, depending on the industry or the industrial process.

(7) Agricultural wastes - Agricultural wastes are waste and residues resulting from diverse agricultural activities such as the planting and harvesting of row, field, tree and vine crops; the production of milk, the production of animals for slaughter, and the operation of feedlots. At present, the disposal of these wastes is the responsibility of most municipal and county solid waste management agencies.

(8) Special wastes - Special waste from residential and commercial sources include bulky items, consumer electronics, white goods, yard wastse that are collected separately, batteries, oil and tires. These wastes are usually handled separately from other residential and commercial wastes.

In BACKGROUND OF STUDY

3.1 TheBackground of Amphur Rajburana

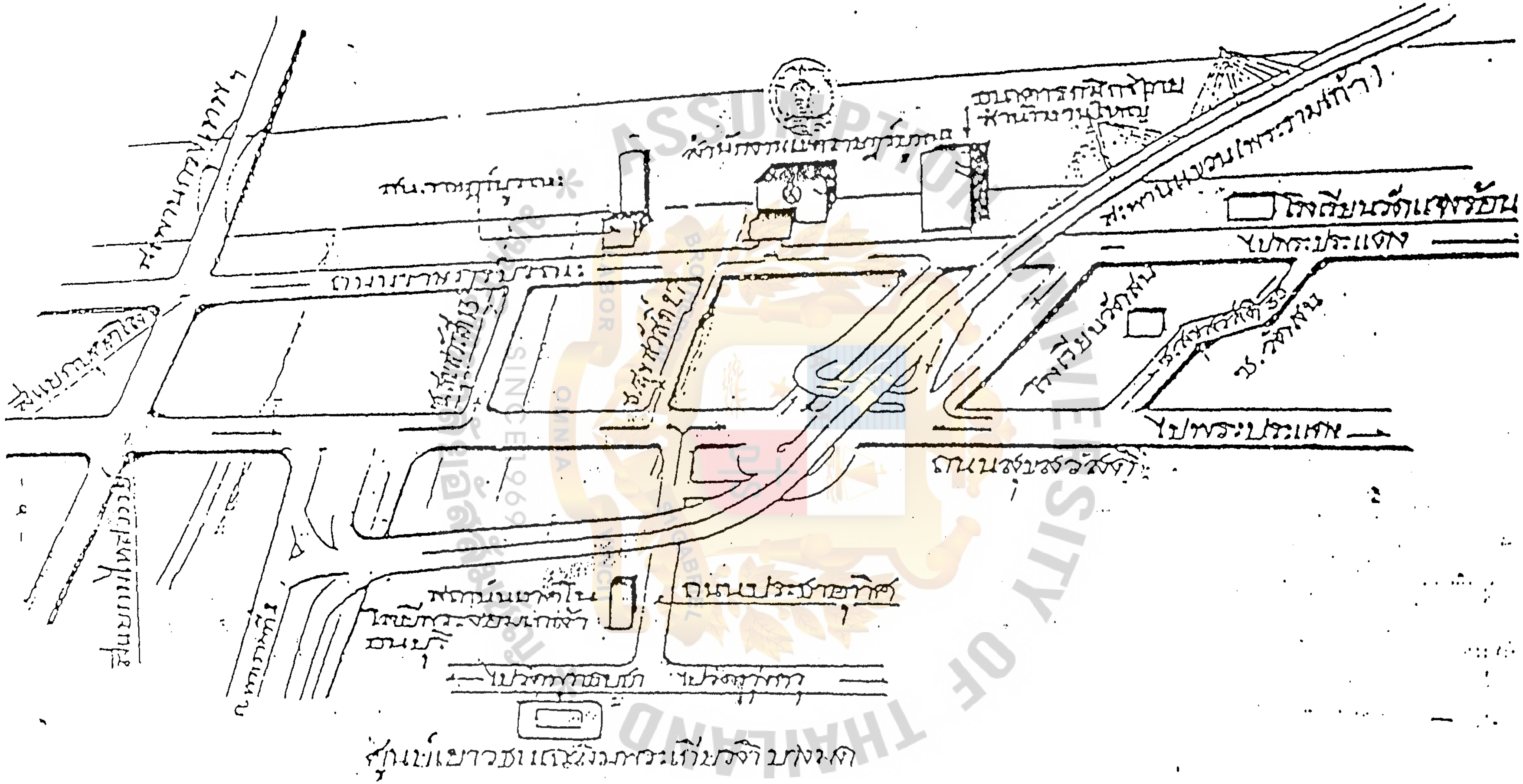
Rajburana is an amphur in Bangkok metropolitan, which is in the southern part of Bangkok, and the original land area was 42.87 km.^{2}.[1] Due to rapid changes in the Bangkok area, together with economic changes, and widening communication, the distribution of population and infrastructures are expanding rapidly. This requires a well-planned policy for administrating to make local people get the benefits and comfortable. On March 1998, the scope area was changed from 42.87 km.^{2} to 15.70 km.^{2} and now includes only two Amphur; Rajburana and Bangpakok, but excludes Tungkru Amphur.

The geographical area of Rajburana is a plateau, so the occupation of most local people is agriculture and gardener. After time and economic change, some areas has been developed from garden to industrial areas or warehouses. Figure 3.1 shows the study area (Rajburana-Bangkok Metropolitan Area)

3.2 Population

According to the data from the municipality of Rajburana, the population of Rajburana is increasing from 140,245 in year 1985 to 183,253 in year 1997 shown as in Table 3.1. It increases by 30.67% within 12 years, but in 1998 the number of population decreases to 95,564 people with the reason of rebordering the scope area of Rajburana Amphur. In August 1998, the registered population in Rajburana was approximately to 95,654 people and number of household was approximately to 29,137, as shown in Table 3.2.

[1] The summary report of Municipality of Rajburana, August 1998, page 9



The Study Area (Rajburana-Bangkok Metropolitan Area).

With the decreasing in number of population in Rajburana, it affects to unable to predict the number of population for the next 10-15 years by run regression from this data.

Table 3.1. The Number of Population in Rajburana from 1985 to 1998 (July 31).

Year	No. of population	Year	No. of Population
1985	140,245	1992	165,001
1986	148,166	1993	168,973
1987	154,177	1994	171,306
1988	154,746	1995	174,330
1989	164,724	1996	179,072
1990	165,818	1997	183,253
1991	169,036	1998	95,564

Source: Center of Demography, Chulalongkorn University

Table 3.2. The Number of Population in Rajburana at August 1998.

District	Men	Women	Total	No. of household
Rajburana	20,551	21,779	42,330	12,412
Bangpakok	26,190	27,134	53,324	16,725
Total	**46,741**	**48,913**	**95,654**	**29,137**

Source: Rajburana Municipality Office

3.3 Rajburana Actitities

From the last year the Rajburana Municipality Office (RMO) was assigned by the Bangkok Metropolitan Administration (BMA) to promote and back up citizens' recycling by classifying waste before being thrown away in order to reduce volume and to save resources. The amount of recovered was 3.4%[2] of the total amount of waste. The RMO tries to provide education and training to stimulate the sanitary officer in classifying the type of waste before treatment. The report of BMA shows that if everyone cooperates to classify and recycle waste before disposal, the volume will decrease by 30%.

RMO has plans to promote "Recycle, Reuse, Classify waste before throwing them away" campaign to school, education institutions, department stores, banks, hotels, and others to increase the waste reduction rate. The RMO expects that the volume of waste will decrease by 5-10% within the next 2-3 years.

3.4 The Composition of Waste in Rajburana

Due to the municipality Rajburana Office doesn't collect the data about the composition of the local waste, as it needs time and high technical knowledge to collect the data. Therefore, the composition of waste in Rajburana is assumed to be same as the composition of waste in Bangkok. The characteristics of which can be categorized into two compositions, which is physical and chemical composition.

Table 3.3 shows the physical composition of waste in Bangkok in 1997, while Table 3.4 shows the chemical composition of waste in 1996. From the table 3.3, it can be concluded that 85.66% is of a combustible composition, 6.77% non-combustion composition and 7.57% other within density at 0.32 kg./litre.

From Table 3.4., it can be concluded that there are 55.15% for moisture content, 34.25% for volatile solid, and 10.60% for ash. And the calorific value of heat value is 1,210.79 kcal./kg.

[2] JICA, The final report for technical assistance on solid waste management (incineration),July 1997, page 46

Table 3.3. The Physical Composition of Waste in Bangkok in 1997.

Composition (wet base)	Percent by weight (average)
Combustible Composition	**85.66**
- Paper	11.39
- Clothes and Textiles	6.17
- Plastic and Foam	17.43
- Grasses and Leaves	5.77
- Food Waste	44.28
- Bones and Shell Shelves	0.00
- Leather & Rubber	0.62
Non-combustible Com u osition	**6.77**
- Metal	2.30
- Glass	4.47
- Stones and Ceramics	0.00
Others	**7.57**
Total	100.00
Density (kg./litre)	**0.32**

Source: Bangkok Municipality Administration report 1998

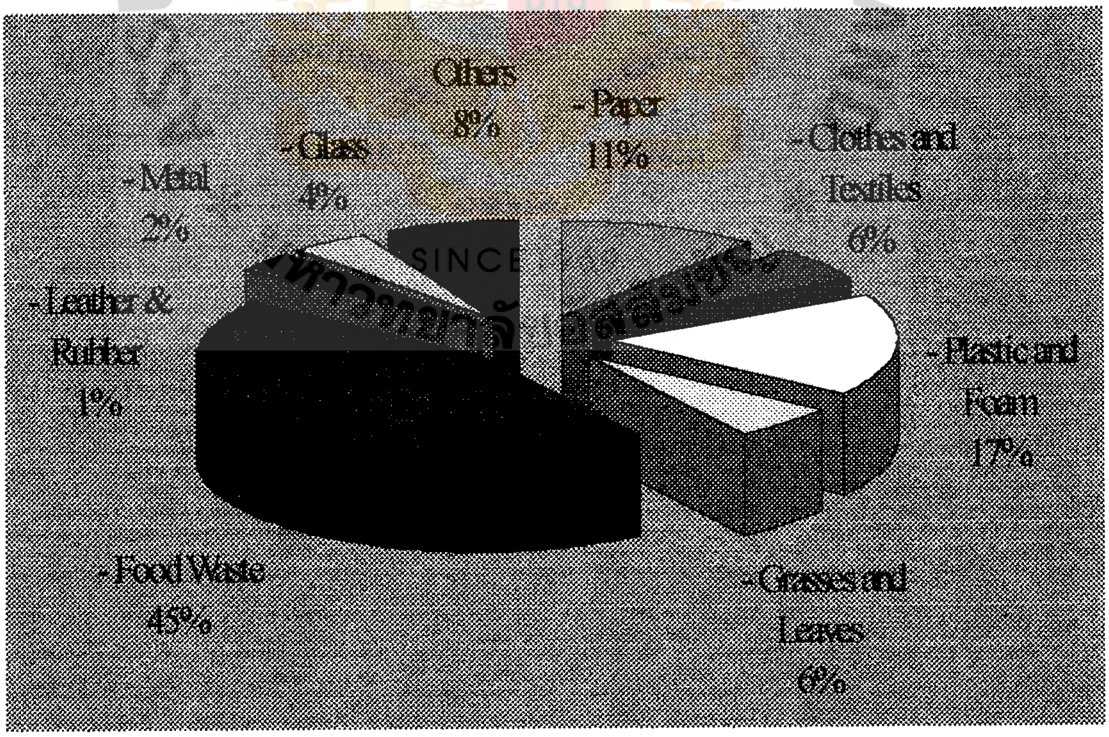


Figure 3.2. **The** Physical Composition of Waste in Bangkok in 1997.

Table 3.4. The Chemical Composition of Waste in 1997 (Average Value).

Chemical Composition	Percentage
1. Moisture Content	55.15%
2. Volatile Solid	34.25%
3. Ash	10.60%
4. Total solids	44.89%
Calorific Value (kcal.kg.)	1,210.79

Source: Bangkok Municipality Administration report 1998

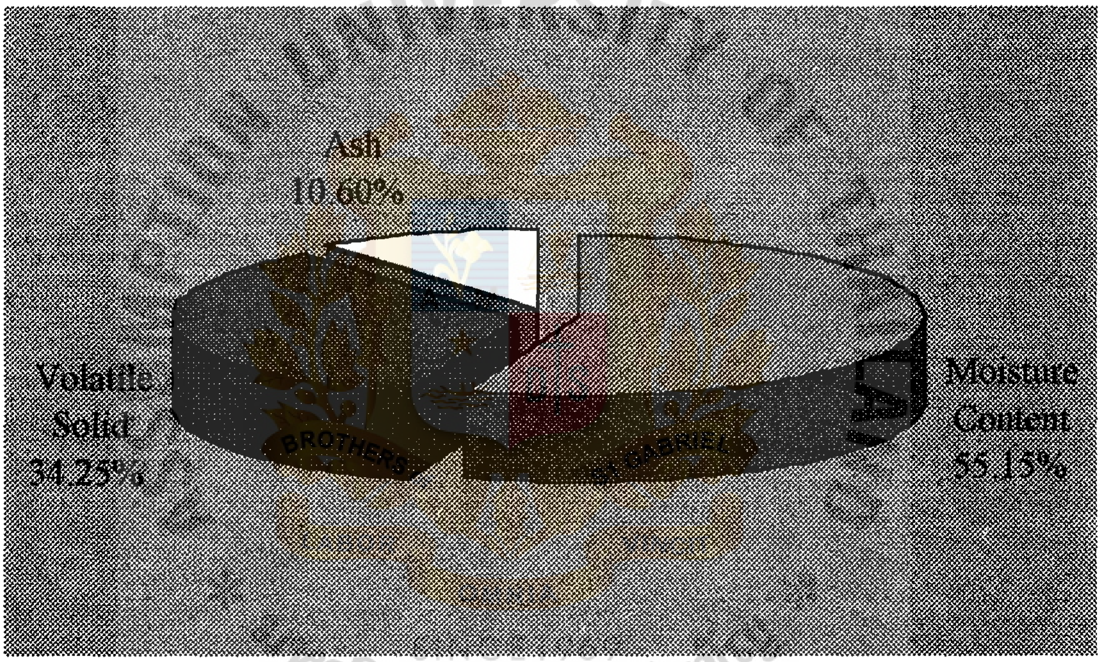


Figure 3.3. The Chemical Composition of Waste in Bangkok in 1997.

3.5 The Volume of Waste in Rajburana

From Table 3.5, the volume of waste in Rajburana is increasing from 185.28 tons/day in 1994 to 226.75 tons/day in 1997, which means it increases by 22.38% tons/day within 4 years. It shows that the volume of waste increases rapidly, and if there is no good measures to prevent this problem in advance, the excess volume of garbage will follow.

The volume of waste in an important factor in determining the waste treatment approach, as it can be used to determine the required capacity of the incineration plant, incinerator, and others. Forecasting the volume of waste in Rajburana needs many factors to run regression, which are number of population, waste generation rate for each type of business and income level. Some factors are not available, so it is hard to predict the volume of waste in the next 10-15 years, or the calculated result is quite unrealistic. The estimated volume of waste in Rajburana in the next 15 years is required, so the estimated volume of waste in Bangkok, which is forecasted by Specialist from JICA,is used as a base to calculated the estimated volume of waste in Rajburana. The calculation used to estimation volume of waste in Rajburana using the Bangkok estimates for next 10-15 years is shown in Appendix B. Table 3.6 shows the estimated volume of waste in Rajburana from 1999 — 2015.

Table 3.5. The Actual Volume of Waste in Rajburana from 1994 to 1998.

Year	Estimated volume of waste (tons/day)
1994	185.28
1995	188.91
1996	215.15
1997	226.75
1998	178.63

Source: The Annual Report of Bangkok Metropolitan Adminstration 1998

Table 3.6. The Estimated Volume of Waste in Rajburana from 1999 to 2015.

Year	Estimated volume of waste (tons/day)	Year	Estimated volume of waste (tons/day)
1999	191.57	2008	307.84
2000	203.84	2009	320.74
2001	216.53	2010	333.22
2002	229.42	2011	345.28
2003	242.32	2012	357.14
2004	255.42	2013	368.58
2005	268.74	2014	379.60
2006	281.84	2015	390.00
2007	294.94		

From the Table 3.6, it can be seen that the estimated volume of waste increases from 191.57 in year 1999 to 390 tons/day in year 2015. This estimated volume of waste generation in the next 15 years will help to select the size and location of the incineration plant.

Before sending the waste to incineration process, the waste needs to be classified into the combustible and non-combustible composition because the non-combustible needs more time and cost for incineration as it generates low heat value, so only the combustible composition of waste (85.66%) will be selected to be put into the incineration process, which it will be called "The Qualified Waste" in this report. Then, the volume of waste which will be incinerated for the next 15 years are in Table 3.7.

Table 3.7. The Estimated Volume forthe Qualified Waste for Incineration.

Year	Total estimated volume of waste	The estimated volume of the qualified waste for incineration (combustible composition only 85.66%)
2001	216.53	**185.48**
2002	229.42	**196.52**
2003	242.32	**207.57**
2004	255.42	**218.79**
2005	268.74	**230.20**
2006	281.84	**241.42**
2007	294.94	**252.65**
2008	307.84	**263.70**
2009	320.74	**274.75**
2010	333.22	**285.44**
2011	345.28	**295.77**
2012	357.14	**305.93**
2013	368.58	**315.73**
2014	379.60	**325.17**
2015	390.00	**334.07**

The next chapter will present about the methodology in collecting the data, which is the another important part in preparing this report because it is the source of the knowledge and information supporting the preparing this project.

IV. METHODOLOGY

This project on waste incineration and treatment incorporates data sources from various institutions and organizations, both public and private. In this section on Methodology, we will examine the sources of data from which we collect our information as well as descriptions and techniques in heat transformation from waste materials.

4.1 Data Collection

To understand the information about incineration technologies and background details of waste in municipality of Rajburana, the procedures involved in the data collection are as follows:

(1) Literature Review on government and public reports and studies

(2) The Background data in the aspects of Bangkok waste, waste treatment by municipality of Bangkok, waste treatment by incineration, background information about Rajburana, forecast the quantity of waste in Rajburana.

(3) Interviews with relevant government officers and other people concerned who provided information on the data and data sources, such as:

   (a) The staff of the Research and Planning Division, Bangkok Metropolitan Administration, Khun Woranut and Khun Watcharaporn

   (b) The General Administrative Staff level 6, Rajburana Municipality Office, Khun Thaweesup Buangam

   (c) The Head of Cleaning Department, Rajburana Municipality Office, Khun Manus U-nam.

4.2 The Sources of Data

The sources of data for analyzing are

(a) Rajburana Municipality Office

(b) Bangkok Municipality Office

(c) Energy Research Institute, Chulalongkorn University

(d) The Central Library, Chulalongkorn University

(e) The information on internet

(f) The web site of EGAT : http://www.egat.or.th

The data for preparing this project is both primary data and secondary data, the primary data of which are interview the authorities concerned. This method took a long time to collect, but the cooperation and the data from all of the government officers, has helped to prepare this project for completion. The secondary data, also took a long time to search out as there are only a few incineration plants in Thailand that can generate electricity. The low technological advance in waste treatment by incineration in Thailand is another reason why it took quite a long of time to search for the information.

The financial data is scarce and some of the information is unusable because of many reasons, such as some financial data is from JAPAN in year 1990 and some is from too big incineration plants with old technological advances. So the economic part for the next chapter needs a lot of assumptions. The results of which may not be accurate, but they are the best estimates for this project.

The next chapter will present about the costs and benefits from selecting the incineration method to eliminate the waste. The cost includes the land cost, construction cost, and operating cost. While the benefits are presented in form of direct and indirect benefits, some benefits can't describe in the form of quantitative, as they are invisible benefits to the locality.

V. CASE STUDY

This chapter has the concept of applying incineration technology for treating waste by selecting Amphur Rajburana as sample. It includes the incineration plant capacity, space requirement, cost estimation, benefit deriving, and cost-benefits analysis for incineration. The data in this chapter may largely change depending on given conditions such as incinerator model and type, plant location, existing infrastructure, fluctuation of socio-economic indices, and additional requirements, if any. The costs and specifications given in this report are based on several assumptions.

5.1 Outline of the Incineration Plant

The plant size is basically composed of lots for main plant building, stack, office building, attached facilities, inside landfill for residue and waste from shortage capacity. Normally the incineration plant requires 40 m^2/tons', but this may depend on many reasons, such as for material stock, and for future extension.

In general, a life span of an incineration plant and facilities is around 20 years, though it largely depends on the quality of the maintenance. But the incineration plant and facilities in this report is assumed to have 10 years for ease of calculation and because the estimated volume of waste is predicted for year 2015 only. clearly.

The incineration plant will be located in Amphur Rajburana due to avoiding the resistance from neighbourhood of the plant, and lowering the waste collection and transport to the plant, and other reason mentioned in chapter III. This Amphur is selected as a sample to test whether it is feasible to invest time and money for waste treatment by incineration method or not.

J1CA, Final Report on technical assistance on solid waste management (incineration)-July 1997, page 26

The incineration plant with capacity of 400 tons/day is recommended because it has to receive the overall estimate volume of waste before sending to the incineration process, which is approximately to 333.22 tons/day. While the selection of the incinerator is still problem. So the comparative between cost and capacity will be applied in order to select the size of incinerator capacity. But the main criteria in selecting size of incinerator is volume of waste in the future, and the waste characteristic, the cost of incinerator, and the cost of land for landfill the waste from shortage capacity. The volume of qualified waste in 2010 is approximately to 284.44 tons/day. So the incinerator with capacity of 300 tons/day should be selected, but it needs to estimate the cost to support the decision making.

From Table 5.1, the incinerator with capacity at 300 tons/day is recommended to use for Amphur Rajburana because it generates the lowest cost and no overload capacity occurs. Although there is high excess capacity, it can be shut down for repair and maintenance for once a month. So the excess capacity will not be too high. And the capacity can be expanded to 400 tons/day for future extension due to limitation of the size of incineration plant. With the incinerator has capacity at 300 tons/day, the volume of waste can be reduced to 731,109 tons for ten years or 73,110.90 tons per year (by average).

The next section will present the cost estimation for land, plant and equipment construction, and operating cost. The cost of land will cover the land for setting the incineration plant, and for landfill the residue. While the cost of plant and equipment include the construction the incineration plant and equipment purchase and installation.

Table 5.1. Cost and Capacity Comparative for Various Size of Incinerator.[2]

	Case 1	Case 2	Case 3	Case 4	Case 5	[redacted]
Estimated Volume for Incineration (tons/year)	860,128	860,128	860,128	860,128	860,128	[redacted]
Capacity (tons/year)	930,750	730,000	949,000	912,500	1,131500	[redacted]
Shortage Capacity (tons/year)	50,944	106,932	35,767	27,931		[redacted]
Excess Capacity (tons/year)	121,566	6,570	124,639	80,303	271,372	[redacted]
Volume of Residue (tons/year)	121,378	108,515	123,655	124,830	129,019	[redacted]
Volume of Waste Reduced (tons/year)	687,809	614,916	700,712	707,367	731,109	[redacted]
Net Present Value (million Baht)	**3,005.63**	**3,231.67**	**2,993.48**	**2,875.56**	**2,948.76**	[redacted]

Note: Case 1: Incineration plant with incinerator capacity at 150 tons/day in the first three years and additional capacity at 150 tons/day in the next seven years

Case 2: Incineration plant with incinerator capacity at 200 tons/day for the next 10 years

Case 3: Incineration plant with incinerator capacity at 200 tons/day in the first six years and additional capacity at 150 tons/day in the next four years

Case 4: Incineration plant with incinerator capacity at 250 tons/day for the next 10 years

Case 5: Incineration plant with incinerator capacity at 250 tons/day in the first six years and additional capacity at 150 tons/day in the next four years

Case 6: Incineration plant with incinerator capacity at 300 tons/day for the next 10 years

5.2 Cost Estimation from Treating Waste by Incineration Method

Cost is the another factor that helps to make the decision on whether treating waste by incineration is feasible or not. The cost of investing in setting up the incineration plant are land cost and construction cost.

5.2.1 Land Cost

To calculate the cost of land for incineration plant needs to calculate the area required, which can be separated into two purposes, which are land for setting the incineration plant and land for landfill. The average area per ton of waste for constructing incineration plant is 40 m^2, while the average area per ton of waste for landfill is 0.16667 tons/m^2.

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[2] See Appendix H

(1) The land cost for setting up the incineration plant

(a)	The average area required for incineration plant	40 m^2
(b)	The expected capacity for incineration plant	400 tons
(c)	The estimated land required for incineration plant ($40\ m^2 * 400$ tons $= 16{,}000\ m^2$), or	4,000 wah^2[3]
(d)	The cost of land for construction the incineration plant ($4{,}000\ wah^2 * 17{,}500\ Baht/Wah^2$)	**70 million Baht**

(2) The land cost for landfill the residue

The average area required for landfill varies depending on the residue after incineration in each year. But for easy calculation, the average area required is approximately to 0.16667 ton/m^2 as mentioned above. The total volume of residue from 2001 to 2010 is approximately to 129,019 tons, so the land required for landfill the residue is approximately to 21,504 m^2 or 5,376 wah^2 , the cost of which is approximately to 94 million Baht. Table 5.2 shows the cost of land required for landfill the residue

So the total land cost for incineration plant and landfill are as follows

(a)	Land for constructing the incineration plant	70	Million Baht
(b)	Land for landfill for residue	94	Million Baht
(c)	Total Land Cost	164	Million Baht

[3] 1 $wah^2 = 4\ m^2$

Table 5.2. Cost of Land Required for Landfill the Residue.

(unit: tons/day)

Year	Estimated Volume of waste	Estimated volume for incineration	Capacity	Incineration			Ash landfill area		
				waste amount	Reduce (85%)	Residue (15%)	m2/year	wah2/year	cost of land Baht/Wah2
2001	216.53	185.48	300.00	185.48	157.66	27.82	1,692.54	423.13	7,404,841.42
2002	229.42	196.52	300.00	196.52	167.04	29.48	1,793.29	448.32	7,845,650.57
2003	242.32	207.57	300.00	207.57	176.44	31.14	1,894.13	473.53	8,286,801.70
2004	255.42	218.79	300.00	218.79	185.97	32.82	1,996.52	499.13	8,734,792.39
2005	268.74	230.20	300.00	230.20	195.67	34.53	2,100.64	525.16	9,190,306.58
2006	281.84	241.42	300.00	241.42	205.21	36.21	2,203.04	550.76	9,638,297.26
2007	294.94	252.65	300.00	252.65	214.75	37.90	2,305.44	576.36	10,086,287.94
2008	307.84	263.70	300.00	263.70	224.14	39.55	2,406.27	601.57	10,527,439.07
2009	320.74	274.75	300.00	274.75	233.53	41.21	2,507.11	626.78	10,968,590.21
2010	333.22	285.44	300.00	285.44	242.62	42.82	2,604.66	651.16	11,395,378.28
per day	**2,751.01**	**2,356.52**	**3,000.00**	**2,356.52**	**2,003.04**	**353.48**	-	-	-
per year	**1,004,119**	**860,128**	**1,095,000**	**860,128**	**731,109**	**129,019**	**21,504**	**5,376**	**94,078,385**

note : (1) The volume of residue 1 ton requires 0.16667 m^2 for landfill

(2)1 $Wah^2 = 4\ m^2$

(3) average price of land is 17,500 Baht/wah2 (appendix F)

5.2.2 The Construction Cost for Incineration Plant

(1) Mechanical & Electrical Work Equipment[4]

1.	Waste reception system (v)	37.20	million Baht
2.	Incineration system(v)	99.60	million Baht
3.	Gas cooling system(v)	94.80	million Baht
4.	Gas treatment system(v)	175.20	million Baht
5.	Waste water treatment system(f)	35.60	million Baht
6.	Heat utilization system(f)	148.00	million Baht
7.	Air supply system(v)	56.40	million Baht
8.	Ash handling system(f)	54.80	million Baht
9.	Electrical equipment(v)	97.20	million Baht
10.	Measuring & control system(f)	211.20	million Baht
11.	Auxiliary equipment(f)	78.40	million Baht
12.	Test run(f)	18.80	million Baht
13.	Others(f)	156.80	million Baht
	Subtotal	1,264.00	million Baht

(2) Building Work (16,000 m^2)[5]

1.	Building and Stack	884.00	million Baht
2.	Building equipment	161.20	million Baht
3.	Miscellaneous	29.60	million Baht
	Subtotal	1,074.80	million Baht
	Total	2,338.80	million Baht

Note: The cost is applied based on the incineration plant with capacity 1,000 tons/day

[4] (v) refers to variable cost, proportionally calculated from 250 tons of 1,000 tons/day capacity of incinerator and (f) refers to fixed cost, proportionally calculated from 400 tons of 1,000 tons/day capacity of incineration plant, 1,000 tons/day capacity is shown in appendix F

[5] refers to variable cost, proportionally calculated according to land required (16,000 m^2/40,000 m^2)

5.2.3 Estimation Cost of Operation and Maintenance

From Appendix F, the operation and Maintenance cost for incineration plant with 1,000 capacity is approximately to 136 million Baht or 2.15% of the construction cost. So it is assumed that the operational and maintenance cost is approximately to 2% of total construction cost.

The total construction cost for the incineration with 300 tons/day capacity is 2,338.80 million Baht, so the operation and maintenance cost is approximately to 46.78 million Baht per year. Therefore, the initial investment cost for setting up the incineration plant is approximately to 2,549.66 million Baht for the first year and the operating cost is 46.78 million Baht for every year within 10 years.

5.3 Benefit Estimation

The benefits from waste incineration is divided into direct benefits and indirect benefits. Direct benefits are the benefits which people derive directly from treating waste by incineration. While the indirect benefits are the benefits which people derive indirectly from treating waste by incineration. Some can't be measured in micro analysis because it provides the beneficiaries to the nation and overall people. Both direct and indirect benefits can be subdivided into quantitative and qualitative benefits also. The quantitative benefits are benefits that can be measured in value terms from treating waste by incineration, while the qualitative benefits are benefits that cannot be measured or estimited from treating waste by incineration.

5.3.1 Direct Benefits

The direct benefit are as follows

(1) Quantitative Benefits

(a) Volume of Waste Reduction

The primary advantage of treating waste by incineration is the ability to reduce volume of waste. The actual volume reduction varies tremendously by in practice. From this plant, the volume of waste can be reduced from 1,004,119 tons to 731,109 tons from year 2000 - 2010, or approximately 72.81% of the original size, or 85% of the estimated qualified waste.

(b) Land Saved Cost

As a result of waste reduction by waste incineration, it can save the land for landfill the waste approximately to 121,854 m^2 or 76 rai, which can save land cost to approximately 533.11 million Baht (applying the estimated price of land at year 1994). Table 5.3 shows the volume of waste reduction and land saved cost. This incineration method is recommended for the large city, which the price of land is high and the space is unavailable.

(2) Qualitative Benefits

(a) Lowering the hospitalization cost

Besides waste treatment by incineration method can reduce the volume and weight of waste, it can reduce the hospitalization cost for the public due to less pollution, less bacteria, germs, fungus in the waste which lead to many diseases also. If it can be calculated, it should be high amount of money that people have to pay for hospitalization cost by the result of pollution from waste.

(c) Keep Transport efficiently

From viewpoint of waste transportation, the incineration plant can be regarded concurrently functioning as a transfer station, and it may be well be located near the collection areas, and this will help not only. Keep transport efficient but raising collection efficiency also. The government spending will be lower if the waste is treated by incineration method because the government can reduce the garbage truck purchasing budget for transporting the waste to distant area to eliminate. Besides it keeps transport efficiently, it also saves the fuel consumption of the garbage trucks.

5.3.2 Indirect Benefits

Indirect Benefits are as follows:

(1) Quantitative Benefits

The quantitative of indirect benefits deriving from treating waste by incineration method are:

(a) Electricity generated by waste incineration

Due the waste can generate electricity and heat as energy recovery, the incineration plant can earn money to support its activities and provide benefits to public also. The average heat value of Bangkok is 1,210.79 kcal/kg. The unit power generation per one ton of waste is estimated about 60-200 kWh/ton[6] of waste or more at the heat value of waste 1,500 kcal/kg. This section has three assumptions, which are:

[6] Final Report for Technical Assistance on Solid Waste Management (Incineration) - July 1997 by JICA, page 73

Table 5.3. The Waste Reduction and Land Saved Cost.

(unit:tons/day)

Year	Estimated Volume of waste	Estimated volume for incineration	Capacity	Incineration			Land save		
				Waste Amount	Reduce (85%)	Residue (15%)	m2/year	wah^2/year	Cost (Baht/wah2)
2001	216.53	185.48	300.00	185.48	157.66	27.82	9,591.03	2,397.76	41,960,768.05
2002	229.42	196.52	300.00	196.52	167.04	29.48	10,161.99	2,540.50	44,458,686.58
2003	242.32	207.57	300.00	207.57	176.44	31.14	10,733.38	2,683.35	46,958,542.99
2004	255.42	218.79	300.00	218.79	185.97	32.82	11,313.64	2,828.41	49,497,156.86
2005	268.74	230.20	300.00	230.20	195.67	34.53	11,903.64	2,975.91	52,078,403.94
2006	281.84	241.42	300.00	241.42	205.21	36.21	12,483.89	3,120.97	54,617,017.81
2007	294.94	252.65	300.00	252.65	214.75	37.90	13,064.14	3,266.04	57,155,631.68
2008	307.84	263.70	300.00	263.70	224.14	39.55	13,635.54	3,408.89	59,655,488.09
2009	320.74	274.75	300.00	274.75	233.53	41.21	14,206.94	3,551.73	62,155,344.50
2010	333.22	285.44	300.00	285.44	242.62	42.82	14,759.73	3,689.93	64,573,810.23
per day	**2,751**	**2,357**	**3,000**	**2,357**	**2,003**	**353**	-	-	-
per year	**1,004,119**	**860,128**	**1,095,000**	**860,128**	**731,109**	**129,019**	**121,854**	**30,463**	**533,110,851**

note : (1) 1 ton requires 0.16667 $metre^2$ for landfill

(2) 1 rai = 1600 $metre^2$

(3) average price of land is 17,500 Baht/wah2 (appendix F)

(1) The unit of power generation is assumed to be 100 kWh/ton of waste.

(2) All electricity generated is assumed to be for sale for cost comparison.

(3) And due to unavailable number of peak generation, it is assumed that the number of peak generation is approximately to 10% of power generation.

Table 5.4 shows the volume of electricity generated by waste incineration and revenue earned from selling Electricity to Electricity Generating Authority of Thailand (EGAT). The unit of electricity generated from waste incineration is approximately to 6-10 million kWh/year, which earn revenue around 115-177 million Baht per year.

Table 5.4. The Volume of Electricity Generated by Waste Incineration and Estimated Revenue Earned for the year 2001 — 2010.

Year	The estimated volume of waste incineration (tons/day)	a) The power Generation (100 Kwh/ ton of waste)		h) The Estimated Revenue from Selling Electricity		Total Estimated Revenue from Selling Electricity (Baht/year)
		(Kwh/day)	(Kwh/year)	(Energy Price)* (Bahtlyear)	Capacity Price ** (Baht/year)	
2001	185.48	18,547.96	6,770,005.33	5,889,904.63	109,507,154.66	115,397.059.29
2002	196.52	19,652.12	7,173,022.78	6,240.529.82	116,026.099.95	122,266.629.77
2003	207.57	20,757.13	7,576,352.89	6,591,427.01	122,550,102.60	129,141,529.62
2004	218.79	21,879.28	7,985,936.18	6,947,764.47	129,175,252.59	136,123,017.06
2005	230.20	23,020.27	8,402,397.97	7,310,086.23	135,911,664.63	143,221,750.86
2006	241.42	24,142.41	8,811,981.26	7,666,423.69	142,536,814.62	150,203,238.31
2007	252.65	25,264.56	9,221,564.55	8,022,761.16	149,161,964.60	157,184,725.76
2008	263.70	26,369.57	9,624,894.66	8,373,658.35	155,685,967.26	164,059,625.61
2009	274.75	27,474.59	10,028,224.77	8,724,555.55	162,209,969.91	170,934,525.46
2010	285.44	28,543.63	10,418,423.20	9,064,028.18	168,521,563.18	177,585,591.36
Total	**2,357**	**235,652**	**86,012,804**	**74,831,139**	**1,391,286,554**	**1,466,117,693**

Note: a) It is assumed that the unit power generation per one ton of waste is estimated about 100 kWh/ton
b) * The Energy Payment of EGAT is 0.87 Baht/kWh
** The Capacity Payment of EGAT is 164 Baht/kWh/month, due to the the peak generation for each month is always changed, so it is assumed that the peak generation is 10% of the power generation per day and multiplying with 30 days to be a month.

Due to the regulation of EGAT about the Domestic Power Purchase, the incineration plant should be Small Power Producer typed firm contract because its terms of contract exceeds five years, and the total hours of electricity production is not less than 4,672 hours per year, The EGAT will pay 164 Baht/kW/month for firm contract for capacity payment, and 0.87 Baht/kWh for energy payment. (Announcement on September 3, 1996).

(b) Government Budget Saving

The Bangkok Metropolitan Administration (BMA), Cleansing Department can save the budget for hiring the private to eliminate the waste, which its cost is 2,000 Baht per ton[7], or.1,720.26 million Baht as shown in Table 5.5.

Table 5.5. The Estimated Budget Saved from Treating Waste by Incineration.

Year	The estimated Volume of waste Incineration (tons/day)	The estimated budget saved from hiring private to treating waste (2000 Baht/ton)	
		per day	per year
2001	185.48	370,959.20	135,400,106.54
2002	196.52	393,042.34	143,460,455,56
2003	207.57	415,142.62	151,527,057.76
2004	218.79	437,585.54	159,718,723.56
2005	230.20	460,405.37	168,047,959.32
2006	241.42	482,848.29	176,239,625.12
2007	252.65	505,291.21	184,431,290.92
2008	263.70	527,391.49	192,497,893.12
2009	274.75	549,491.77	200,564,495,32
2010	285.44	570,872.50	208,368,463.96
Total	**2,356.52**	**4,713,030.33**	**1,720,256,071.18**

[7] Announcement of Bangkok Metropolitan Administration at 6th March 1998, service rate for eliminating waste from Annual 1998 of Bangkok Metropolitan Administration-Cleansing Department, page 160

(2) Qualitative Benefits

The qualitative of indirect benefits deriving from treating waste by incineration are:

(a) The electricity generated by waste incineration could be a source of import substitution for increasingly expensive fuel, it is energy recovery.

(b) Reducing the fuel imported helps to elevate the deficit of the international balance of payment due to less loss from exchange currency.

(c) It helps people consume the electricity at cheaper price due to the F_t in calculating the cost of electricity decreases. (The loss from exchange rate is included in F_t which used in calculation the electricity price by EGAT)

Table 5.6. The Total Benefits Summary.

(unit: Baht)

Year	Direct Benefits		Indirect Benefits		Total Benefits
	Volume of waste Waste Reduction (tons/ year)	Land Saved Cost	Revenue from selling Electricity	Government Budget Saving from hiring private to treating waste	
2001	57,545.05	41,960,768	115,397,059.29	135,400,107	292,757,934
2002	60,970.69	44,458,687	122,266,629.77	143,460,456	310,185,772
2003	64,399.00	46,958,543	129,141,529.62	151,527,058	327,627,130
2004	67,880.46	49,497,157	136,123,017.06	159,718,724	345,338,897
2005	71,420.38	52,078,404	143,221,750.86	168,047,959	363,348,114
2006	74,901.84	54,617,018	150,203,238.31	176,239,625	381,059,881
2007	78,383.30	57,155,632	157,184,725.76	184,431,291	398,771,648
2008	81,811.60	59,655,488	164,059,625.61	192,497,893	416,213,007
2009	85,239.91	62,155,344	170,934,525.46	200,564,495	433,654,365
2010	88,556.60	64,573,810	177,585,591.36	208,368,464	450,527,866
Total	731,109	533,110,851	1,466,117,693	1,720,256,071	**3,719,484,615**

Table 5.6 shows the benefit summary for both direct and indirect benefits for quantitative analysis. The total value of benefits that can be estimated are 3,719.48 million Baht at year 2010.

5.4 Cost-Benefit Analysis

To measure quantitatively the net benefit of the project, benefit/ cost ratio is employed by selecting the measurable items. The cost—benefit ratio is used in conjunction with a present-worth analysis. It is utilized on many government and public works projects to determine if the expected benefits provide an acceptable return on the estimated investment and costs.[8]

By assuming that the government through bond issuing will finance the investment, the 7.95%[9] yield-to-maturity rate of current 10-year government bond is applied as the discount rate in this calculation. Measurable benefits include the direct benefits and indirect benefits (Table 5.6) in quantitative.

Table 5.7. The Benefit Versus Cost.

(unit: Bak)

Year	Initial Investment cost	Salvage Value Value at the year 10	Land Sale at the year 10	Present value of Total Cost	Total Benefits	Present Value of Total Benefit
2000	2,549,660,000			2,549,660,000		
2001	46,780,000			43,334,877	292,757,934	271,197,715
2002	46,780,000			40,143,471	310,185,772	266,180,710
2003	46,780,000			37,187,097	327,627,130	260,442,537
2004	46,780,000			34,448,446	345,338,897	254,305,007
2005	46,780,000			31,911,483	363,348,114	247,861,844
2006	46,780,000			29,561,355	381,059,881	240,800,480
2007	46,780,000			27,384,303	398,771,648	233,434,879
2008	46,780,000			25,367,580	416,213,007	225,701,515
2009	46,780,000			23,499,380	433,654,365	217,841,141
2010	46,780,000	-1,169,400,000	-164,080,000	-598,757,318	450,527,866	209,650,157
Total	3,017,460,000			**2,243,740,674**	3,719,484,615	**2,427,415,986**

[8] Blank Tarquin, Engineering Economy, 4th Edition, McGRAW-I{ELL International Edition, 19978, page 278
[9] The Yield of Government bond with 10 year maturity at October 4, 1999, 7.95%

The summary of the costs is:

Land	164.08	million Baht
Total Cost of Construction	2,338. 80	million Baht
Maintenance Cost	46.78	million Baht (per year)
Salvage Value of the Plant	(1,169.40)	million Baht (at year 10)

Market Price of Land at year 10 assumed conservatively to be the constant

$$\frac{\textbf{Present Value of Benefit}}{\textbf{Present Value of Cost}} = \frac{\textbf{2,427,415,986}}{\textbf{2,243,740,674}} \quad \textbf{1.0819}$$

From the data of the cost and benefit in Table 5.7, the benefit-cost ratio is approximately 1.0819. It indicates that the project evaluated is economically advantageous because if benefit over cost is greater than or equal to 1.0, it means the project should be accepted.

Disbenefit is another factor in subtracting the benefit of the project, but it is not mentioned because it is assumed that no secondary pollution happens from waste generation. If the incineration plant is controlled and managed well, the secondary pollution should not occur.

The next chapter will present about the conclusion and recommendations for this project whether the incineration plant should be invest or not.

VI. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This chapter shows the a conclusion of the overall result study. In principle, the incineration method is recommended for treating waste for the limited area in large cities. This technology will be in due course, replace the current system of using landfill for garbage disposal which will become obsolete. The incineration process is beneficial to the environment if all emission from the process in minimized.

Waste in Rajburana can be burned out with incineration plant as it is. However, introducing sorting collection system is recommendation in order to secure more stable operation.

Considering the fact that the waste needs to be treated in correct way, the incineration system is a good alternative in treating and eliminating waste in large cities, which has limited space. It can assure public hygiene if operating is done in a careful and proper way to utilize waste for recycling or even for energy recovery.

With regard to the benefit and cost analysis, the cost will be increased or decreased depending on many conditions, which are the yield of government bond, the inflation, the construction material, the wage rate, and other factors. Besides the economic factors, the cooperation of the local people in classifying the waste before disposal in order to reduce the volume of waste and save the resources is also a major prerequisite. Therefore; the cost will be affected by these factors. From the previous chapter, the cost-benefit ratio shows am evidence which supports the construction of the incineration in Rajburana with a suggested capacity of 300 tons/day, and its initial investment cost is approximately 2,549.66 million Baht, to avoid the resistance form nearby neighbourhood, and to reduce the garbage problem and the problem of unavailable space for living in the big cities.

6.2 Recommendations

Most of the recommendation in this report is the researcher's opinion, although some are also of the report of the staff of Rajburana concerned. The recommendations are as follows

The Thai Government which controls the Bangkok Metropolitan Administration (BMA) should promote and back up the local people to reduce the volume of waste and to save resources. But practically, the promotion and backing up does not work effectively due to the lack of awareness on the matter, so the government should issue law or regulations to force the people to follow.

To avoid resistance from nearby neighbourhood, the incineration plant may provide the electricity (as by-products) with free of charge or 50% discount for people nearby to persuade people accept the waste treatment by incineration plant and incineration technology. To avoid the resistance for the plant construction, the public hearing and public education must be rigorously applied to this case.

APPENDIX A

THE WASTE REDUCTION RATE

The Waste Reduction Rate

(1)	Total waste in year 1997 is	8,703.25	tons/day
(2)	Combustible Percentage (including food waste)	85.66%[1]	
(3)	Volume of waste to incinerate (1) * (2)	7,455.2	tons/day
(4)	Ash generation ratio	15%[2]	
(5)	The residue (3) * (4)	1,118.28	tons/day
(6)	The volume of waste reduce (3) — (5)	6,336.92	tons/day
(7)	The reduction ratio of its total waste (6)41)	72.81%	

From the calculation above, the reduction rate for incineration method is 72.81%, which will be varied each year depending on the percentage of combustible composition of waste.

1 See Table 2.1

2 Masharu Yoshida-JICA, Final Report for technical assistance on solid waste management (incineration), July 1997

APPENDIX B

THE ESTIMATION OF THE VOLUME OF WASTE IN RAJBURANA
FROM 1999 TO 2015

The Estimation of the Volume of Waste in Rajburana from 1999 to 2015

To estimate the volume of waste in Rajburana, the proportion of the waste of Rajburana/Bangkok is required. From the Table 3.5, the actual volume of Rajburana waste in 1998 is 178.63, while the actual volume of waste in Bangkok is 8,591.72[3], making the proportion of the volume of waste of Rajburana/Bangkok is 178.63/8591.72 = 2.08%.

Next, it needs to use this proportion find out the estimated volume of waste in Rajburana by multiplying the proportion (2.08%) with the estimated volume of Bangkok waste in Table Bl. The estimated volume of waste in Rajburana from 1999 to 2015 will be resulted in Table B.2. Table B.2 shows the estimated volume of waste in Rajburana from 1999 to 2015.

Table B.1. The Estimated Volume of Waste in Bangkok from 1999 to 2015.

Year	Estimated volume of waste (tons/day)	Year	Estimated volume of waste (tons/day)
1999	9,210	2008	14,800
2000	9,800	2009	15,420
2001	10,410	2010	16,020
2002	11,030	2011	16,600
2003	11,650	2012	17,170
2004	12,280	2013	17,720
2005	12,920	2014	18,250
2006	13,550	2015	18,750
2007	14,180		

Source: The Bangkok Metropolitan Administration

[3] The Bangkok Metropolitan Administration report 1997, page 41

Year 1999 – Estimated volume of waste (tons/day) * proportion of the volume of waste of Rajburana/Bangkok

- 9,210 * 2.08%

- 191.57 tons/day

Table B.2. The Estimated Volume of Waste in Rajburana from 1999 to 2015.

Year	Estimated volume of waste (tons/day)	Year	Estimated volume of waste (tons/day)
1999	191.57	2008	307.84
2000	203.84	2009	320.74
2001	216.53	2010	333.22
2002	229.42	2011	345.28
2003	242.32	2012	357.14
2004	255.42	2013	368.58
2005	268.74	2014	379.60
2006	281.84	2015	390.00
2007	294.94		

APPENDIX C

WASTE CHARACTERISTICS

Waste Characteristics

Characteristic of waste can be expressed in terms of physical and chemical composition as well as technical analysis values. Composition is used to describe the individual components that make up a solid waste stream and their relative distribution, usually based on percent by weight. Information on the composition of solid waste is important in selecting and operating equipment needs, facilities in assessing the feasibility of incineration plant

(1) Physical Characteristic

The physical composition of waste can be divided into density and composition. The density is the proportion of weight of waste to the volume of waste. The density has a divert relationship with the physical element or composition of waste. If there are high volume of plastic and paper, the density will be low. But if there are high volume of food waste, the density of waste will be high. The density will be useful for considering the size of compactor or garbage trucks and time for landfill method.

The another physical characteristic of waste is composition. It can be classified into combustible composition and non-combustible composition, and others. The combustible composition includes food waste, plastic, papers, clothes and textiles, leaves and grasses, rubber and bones. While the non-combustible composition includes metal, glass, stones and ceramics. The composition characteristic will be used for considering the waste treatment method. For example, the waste that composes with the high percent in food should be treated by composting, while the waste that composes with glass, plastic or metal should be recycled. Table Cl. shows the average physical composition of waste in Bangkok in 1997.

Table C.1. Physical Composition of Waste in Bangkok in 1997

Composition (wet base)	Percent by weight (average)
Combustible Composition	**85.66**
- Papers	11.39
- Clothes and Textiles	6.17
- Plastic and Foam	17.43
- Grasses and leaves	5.77
- Food waste	44.28
- Bones and shell shelves	0.00
- Rubber and elastic	0.62
Non-combustible Composition	**6.77**
- Metal	2.30
- Glass	4.47
- Stones and Ceramics	0.00
Others	**7.57**
Total	100.00
The density (kg./litre)	**0.32**

Source: Plan and Research Division, Bangkok Municipality Administration

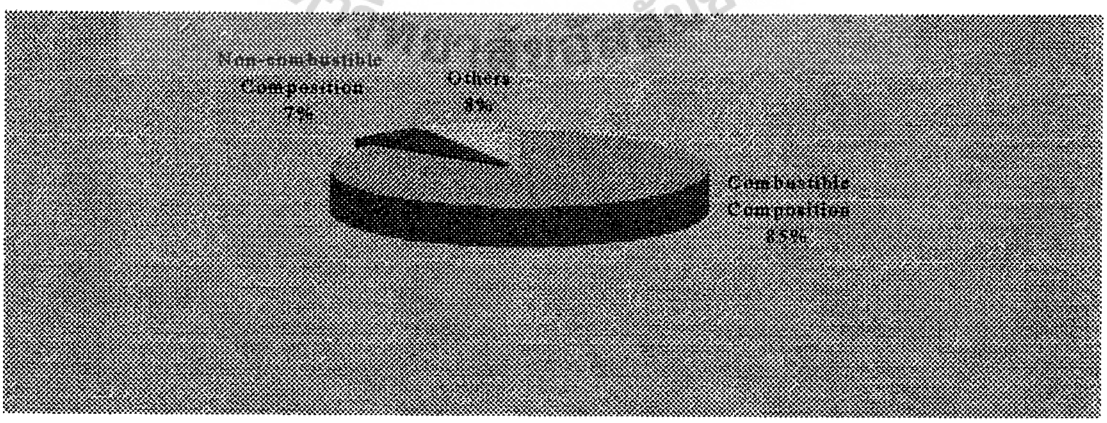

Figure C.1. Physical Composition of Waste in Bangkok in 1997.

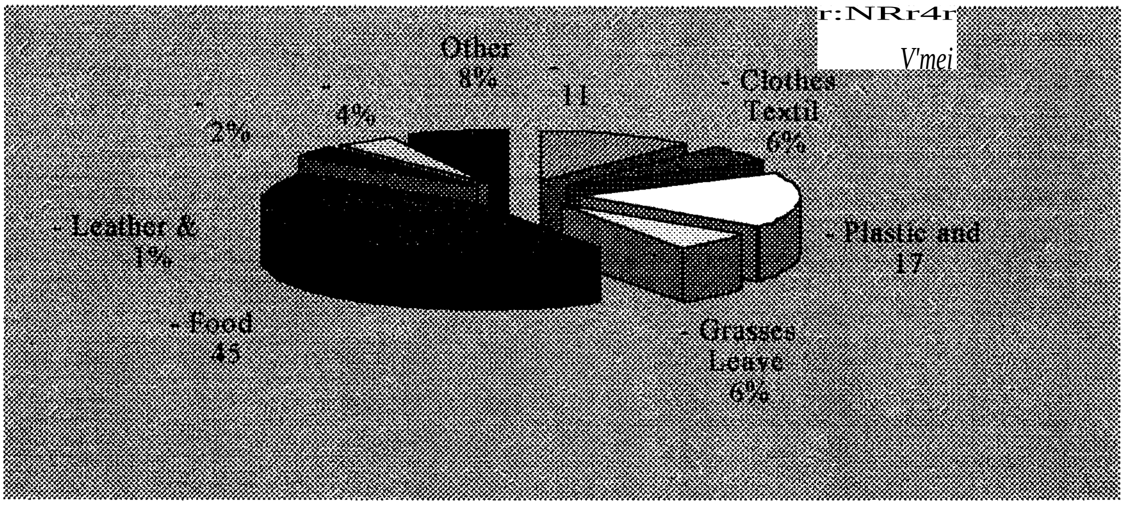

Figure C.2. Physical Component of Waste in Bangkok for the year 1997.

(2) Chemical Composition

The data on chemical composition which are moisture content, volatile solids, total solids, ash, and calorific value is also important in assessing the heat value to generate electricity, investment, cost and environmental impact.

The moisture content is the volume of water in waste. It has a direct relationship with the composition of physical waste. The moisture content is another in determining which methods the waste will be eliminated. For the incineration method, the more moisture content in waste, the less heat generated. The average moisture content of waste in Bangkok in 1997 is 52.12%.

The volatile solid is the solid matters in the waste. After burning, it can generate the evaporator, CO_2, and heat. In the year 1997, the value of the volatile solids in waste in Bangkok is between 31.51% to 38.52% or the average is 34.25%

The ash is the residue after incinerating. From the year 1996, the value of ash is between 8.12% to 12.40% or the average value of ash is about 10.63%

The calorific Value or the heat value from incinerating waste, The calorific value of year 1997 is between 1,058.28 to 1,452.28 kcal/kg, or the average value is 1210.79 kcal/kg.. If it can generate heat to 1,100 — 1,700 kcal/kg., it shows that incinerating method can use this heat to generate electricity. Table C.2 and Figure C.3 shows the average value of the chemical composition of the waste in Bangkok in 1997

Table C.2. The chemical composition of waste in Bangkok in 1997 (average value)

Chemical Composition	Percentage
1. Moisture content	55.12
2. Volatile solid	34.25
3. Ash	10.63
4. Total solids	44.89
5. Calorific value (kcal./kg.)	1,210.79

Source: Plan and Research Division, Bangkok Municipality Administration

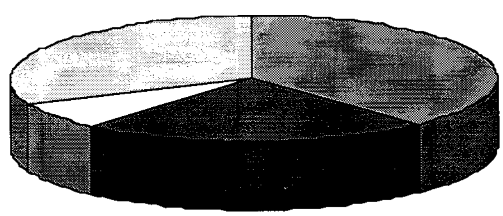

Figure C.3. The Chemical Composition of Waste in Bangkok in 1996 (Average Value).

These data prove that the waste composition have a sufficient level of calorific value which can be used as fuel. This finding tells that it is reasonable in a long term to try to change refuse into energy as effectively as possible which such high quality fuels like fossil fuel, coal, etc. It should be used for more selected purposes because we have to be prepared to the occasion when these natural resources will not be available any more.

APPENDIX D

THE CALCULATION OF THE QUALIFIED WASTE BEFORE SENDING TO THE INCINERATION PROCESS

The Calculation of the Qualified Waste before Sending to the Incineration Process

The qualified waste can be estimated by multiplying the total estimated waste (tons/day) by the percentage of combustion composition of waste, which is 85.66%[4]. The combustible composition of waste in year 1997, it may be varied depending on composition of waste each year It can be calculated as follows

Table D.1. The Volume of Qualified Waste for Incineration (85.66%).

Year	Total Waste (tons/day)	Qualified Waste for incineration (with combustible composition 85.66%) (tons/day)
2000	203.84	174.61
2001	216.53	185.48
2002	229.42	196.52
2003	242.32	207.57
2004	255.42	218.80
2005	268.74	230.20
2006	281.84	241.42
2007	294.94	252.65
2008	307.84	263.70
2009	320.74	274.75
2010	333.22	285.44
2011	345.28	295.77
2012	357.14	305.93
2013	368.58	315.73
2014	379.6	325.17
2015	390.00	334.07

[4] See Appendix C

APPENDIX E

THE LAND ESTIMATED PRICE OF RAJBURANA

The Land Estimated Price of Rajburana

The Land Price is allocated according to the area of the Amphur, the detail about the land price of Rajburana is:

Table E.1. The Estimated Land Price of Rajburana at Year 1994.

Area	Price(Baht)
Beside the Chao Phraya River	10,000 —80,000
Along the Suksawad Road	40,000-55,000
Along the Rajburana Road	35,000-80,000
Along the Pracha-u-tit Road	40,000-60,000
Along the Suksawas 29	25,000
Along the Suksawas29	16,000-20,000
Along the Suksawas29	14,000-18,000
Along the Suksawas 35	10,000-25,000

Source: the estimated Price of Land in Thailand year 1994

The area beside the Chao Phraya River is not selected due to avoiding flood problem. And area along the Rajburana Road, Pracha-u-tit Road, and Suksuwad Road. Road is not available, and avoiding traffic congestion, so it is not selected also.

Then, the cost of land should be averaged between 10,000 — 25,000, so the average estimated price of land in Rajburana is 17,500 Baht/Wah^2.

APPENDIX F

THE EXAMPLE OF THE COST ESTIMATION FOR INCINERATION PLANT WITH 1,000 TONS/DAY CAPACITY

The cost estimation for incineration plant with 1,000 tons/day capacity

Cost Estimates

Unit: Million Baht (Current Price)

1. **Construction Cost**	
1.1 Mechanical & Electrical Work Equipment	
1) Waste reception system	124.00
2) Incineration system	332.00
3) Gas Cooling system	316.00
4) Gas treatment system	584.00
5) Waste waster treatment system	89.00
6) Heat utilization system	370.00
7) Air supply system	188.00
8) Ash handling system	137.00
9) Electrical equipment	324.00
10) Measuring & control system	528.00
11) Auxiliary equipment	196.00
12) Test run	47.00
13) Others	392.00
Sub Total	**3,627.00**
1.2 Building Work	
1) Building and Stack	2210.00
2) Building equipment	403.00
3) Miscellaneous	74.00
Sub Total	**2,687.00**
Total	**6314 00**
2. **Operation and Maintenance Cost (per annual)**	
1) Emolument	16.00
Utility and Maintenance Cost (including OH Cost)	120.00
Total	**136.00**

Source: Final Report for Technical Assistance on Solid Waste Management (Incineration)-July 1997, page 14

APPENDIX G

DOMESTIC POWER PURCHASE

Domestic Power Purchase

Domestic Power Purchase can be divided into 2 types, which are

(1) **IPP - Independent Power Producer**

(a) Background

In 1992, the Government announced the policy of state enterprise privatization encouraging more private sector participation in power development, for reasons of capital requirement, technology transfer, management know-how private sector ingenuity, and efficiency. This also encouraged more competition in the choice of technology and plant location, and thus, reducing construction costs and arriving at an electricity tariff that would benefit consumers the most.

In response to the Government's policy, EGAT has launched an Independent Power Producers (IPP) program incorporating certain IPP project in EGAT's Power Development Plan to allow the private sector to construct and operate large scale power projects and sell electricity to EGAT. The First Solicitation was issued on December 15, 1994 for the power purchase of 3,800 MW power capacity from IPPs with the first stage of 1,000 MW expected for operation within 2000, and the second stage of 2,800 MW in 2001-2002. However, EGAT later announced in April 1995 to increase its power purchase from IPP projects for its 1994 Solicitation by 10%, or approximately 400 MW.

At the closing date of the bid submission on June 30, 1995, a total of 32 bidders submitted totally 50 proposals with a total proposed power capacity of 39,067 MW. All proposals are evaluated by the Subcommittee appointed, from senior representatives of governmental agencies concerned, by the Government.

Nevertheless, according to the load demand forecast in April 1996 by Thailand Load forecast Subcommittee which indicated significant increase of the peak demand over the previous official Load Demand Forecast. The National Energy Policy Council (NEPC) has therefore considered such power demand increase in the July Meeting 1996 and then came up with a resolution on necessity of additional power purchase from the First 1PP Projects to be scheduled for operation during 2000-2003 for another 1,600 MW, totaling 5,800 MW.

(b) Power Purchase Solilicitation

Proposals made by the private investors must be in line with the 1994 Power Purchase Solicitation document which is composed of the three main parts.

(1) Request for Proposals (RFP) - The document providing bidders with evaluation and selection criteria and also guidelines and proposal instructions addressing all issues contained in the model Power Purchase Agreement and Grid Code as well as other relevant issues;

(2) Power Purchase Agreement (PPA) - The Agreement between EGAT and IPP in respect to a single power plant for generation and selling of electricity by the IPP to EGAT. PPA also specifies operating characteristics, availability payments, energy charges, environmental quality standards, fuel stocking and fuel purchase agreement, new

transmission facilities and construction schedule, contracted milestones, liquidated damages, force majeures, etc., and

(3) Grid Code - The document identifying the general system protocol and requirements including connection procedures, power plant operation and generation dispatching that the IPPs have to comply with.

(c) Main issues of the 1994 power purchase solicitation

The characteristics of proposed projects to be operated as base load power plants

(1) Location of power plants, selected by EGAT with preferable sites in the central region, western or eastern coasts. For the first 1,000 MW, preferable sites are locations over which power plants can be built without upgrading existing system due to time constraint. For the next 2,800 MW, preferable sites will be in the western region (for 1,400 MW) and inter eastern areas (for another 1,400 MW).

(2) Fuel sources must be environmentally clean, acceptable to the public, with stable price and assured supplies, and support the national policy of fuel diversification. Choices of fuel include LNG, hydrocarbon gas and its associated liquid, and coal.

(3) Environmental Impact Assessment (EIA) Report must be prepared by IPPs - IPP will be responsible for applying for project construction and operation permits.

(a) IPPs will build, own and operate power plants and also procure fuel for power generation.

(b) Evaluation, selection, and notification of bidding award will be undertaken by the IPP Proposals

(c) Evaluation and Selection Subcommittee which was appointed by the Government.

In evaluating bid proposals, points allocation will be made upon how well and appropriate that price and non-price issues have been organized and proposed, such as project viability, level of development, fuel type and diversity, site location, utilization of local manpower and resources, project connection costs security, experience and ability of the bidder to arrange financing for the construction of the project, technical appreciation of the work to be performed, proposed changes to the Model Power Purchase Agreement, environmental impact, dispatch ability and other factors that may affect overall cost and/or schedule.

(d) IPP Proposal Evaluations

IPP Proposals were evaluated by the Evaluation and Selection Subcommittee (ESC) which was composed of EGAT's Governor and Assistant Governor - New Business Ventures and the representatives from National Energy Policy Office (NEPO), the National Economic and Social Development Board (NESDB) and the Fiscal Policy Office (FPO). Final approval is subject to Board of Directors of EGAT. Evaluation criteria are clearly set forth in the RFP: 60% weight on price factors and 40% weight on non-price factors. Price factors 60% are allocated for availability payment, energy payment and connection cost while Non-price factors 40% are for:

(1) Viability of Project (Level of development 11% + Financial status of bidder and Ability to arrange finance 7% + Experience 7%)

(2) Fuel and Fuel diversity 4%

(3) Other factors (Location 6% + Changes to Model PPA 5%)

Evaluation has been commenced since July 1995 and was completed for stage I on February 8, 1996 with disclosing of 13 proposals, and Stage II on April 17, 1996 with disclosing of 8 proposals in the shortlists. Negotiations have been initiated with top ranked bidders in each stage since April 1996.

(e) Summary of Common negotiated issues

(1) Gas Sales Agreement

(2) Payments in case of Force Majeure and Governmental Force Majeure Events affected both Parties

(3) Events of Defaults and Both Parties' obligations towards the events

(4) Termination right of each Party and Buyout Price

(5) Tariff Reduction

(6) Change-in-Law Adjustment

(7) Environmental Quality Requirement in relation to Change-in-Law Provision

(8) Additional Security

(9) Incentives and Penalties for Operation Performance

(10) New Transmission Facilities Construction

Major issues on discussions involve with balancing of investors' needs, EGAT and the Government of Thailand's concerns over security of power supply and provision of incentives for all prospective successful IPPs to perform obligations in compliance with the PPA throughout the Term. In addition, in PPA, there are also provisions to decrease payments for Availability as a result of loss in IPP's power generation reliability. On the other hand, EGAT responds to provide payments to lenders if EGAT defaults or should there be unforeseen governmental interference.

(f) Additional Power Purchase from IPP Round I

According to the April 1996 Load Forecast prepared by Thailand Load Forecast Subcommittee, it indicated that the peak demand increased significantly above the previous official load demand forecast. The National Energy Policy Committee (NEPC) has already accommodated this new load forecast and assigned EGAT to elaborate the new Power Development Plan (PDP) based on it.

In order to accommodate the new Load Forecast demand in a short term up to 2003, EGAT has already been granted a consent by the NEPC ,and the Cabinet respectively to increase its power purchase from IPP projects for its 1994 Solicitation by 1,600 MW in addition to those 4,200 MW as follows:

Table G.1. Capacity Payment for Firm Contract by EGAT.

Year	Additional Power to be purchased	Remarks
2000	300*	from Stage I Shortlisted Bidder
2002	700	from Stage II Shortlisted Bidder
2003	600	from Stage II Shortlisted Bidder

(g) IPP Project selection

STAGE I

The evaluation of IPP Stage I commenced in July 1995 and completed on February 8, 1996. The ESC selected 13 proposals for IPP Stage I, all of which are proposals utilizing natural gas as fuel. Three proposals located in western region and the other ten located in eastern region. The ESC has EGAT invite the two top ranked bidders, one from western and the other from eastern to negotiate major issues. Up to present, EGAT already signed PPA with the three selected bidders as detailed follows:

(1) The Independent Power Thailand Co., Ltd. with contracted capacity of 700 MW. To generate electricity to EGAT System at Ao-Phai Substation in September 1999. The Term of Power Purchase Agreement is 25 years.

(2) Tri Energy Co., Ltd. with contracted capacity of 700 MW to generate electricity to EGAT System at Ratchaburi 2 Substation in May 2000. The Term of Power Purchase Agreement is 20 years.

(3) Eastern Power and Electric Co., Ltd. with contracted capacity of 350 MW to generate electricity to EGAT System at Khlong Mai Substation in January 2001.

(4) The Term of Power Purchase Agreement is 20 years

STAGE II

(1) With reference to Stage II selection, based on the same regulations as in Stage I, the ESC selected 8 proposals from a total of 28 proposals. Three of them are proposals utilizing gas fuel, four utilizing coal and

one utilizing or emulsion. EGAT invited the four top ranked bidders in the short list below to negotiate major issues:

(a) Union Power Development Co., Ltd.

(b) BW Power Co., Ltd.

(c) BLCP Power Limited

(d) Gulf Power Generation Co., Ltd..

Up to present, EGAT already signed PPA with the four selected bidders as detailed follows:

(a) Union Power Development Co., Ltd. with contracted capacity of 1,400 MW (2 x 700 MW), utilizing coal as fuel, and each unit will generate electricity to EGAT System in September 2001 and December 2001 respectively. The Term of the PPA is 25 years.

(b) Gulf Power Generation Co., Ltd.. with contracted capacity of 734 MW (2 x 367 MW), utilizing coal as fuel, and each unit will generate electricity to EGAT System in October 2001 and April 2002 respectively. The Term of the PPA is 25 years.

(c) BW Power Co., Ltd. with contracted capacity of 713 MW, utilizing natural gas as fuel, to generate electricity to EGAT System in April 2001. The Term of the PPA is 25 years.

(d) BLCP Power Limited with contracted capacity of 1,346.5 MW (2 x 673.25 MW), utilizing coal as fuel, and each unit will generate electricity to EGAT System in October 2002 and February 2003 respectively. The Term of PPA is 25 years.

(e) Impacts of Baht Managed Float on IPP Program

Originally, Availability Payment which is one component of the electricity price was formulated on a criteria that IPPs will solely absorb the exchange risks fluctuation. However, according to the July 2, 1997 announcement by the Ministry of Finance on Adjustment of Currency Exchange System from the former basket of currency supported Baht exchange system to a new managed Baht float system, the IPPs who have either negotiated or are negotiating the Power Purchase Agreements therefore made complaints to EGAT that such change produces critical impacts on finance ability and their project costs, most of which will be obtained from offshore loans especially in US dollars.

Consequently, the Evaluation and Selection Subcommittee has the IPP Project Financial Advisor (Lehman Brothers) expeditiously study the foregoing impacts of the managed float on the seven 1PP projects and assess the need for modifications to specific PPAs within the larger context of EGAT's entire IPP program and EGAT's own financial situation.

After completing review of the study results of this difficult issue in the August 19, 1997 meeting, the Subcommittee has endorsed "Tariff Adjustment Mechanism (TAM)", the addition of an adjustment mechanism to the PPAs to address the implications of the Managed Float and to enhance the finance ability of the IPP projects.

The TAM is an indexed adjustment of certain portions of the Availability Payment to provide IPPs and EGAT a degree of protection against fluctuations from a "base" Baht : USD exchange rate. The TAM will be applied to such three tariff components as Availability Payments (APR1n), Fixed Operation and Maintenance Costs (APR2n), and Added Facility Charge (AFC) (but only, in the case of AFC, for those IPPs which are responsible for building their own transmission facilities; if **IPP** is responsible for reimbursing EGAT for its transmission costs, there is no index of AFC). There is no change to either Variable Operation and Maintenance costs or the Fuel Charge.

The TAM index is weighted differently for each type of power plant and for each of the three components affected. The index weighting for relevant tariff components was determined based on the expected percentage of the actual incurred costs from foreign resource in the construction of the power plant.

The "base" exchange rate for purposes of currency index is pegged at 27 Baht : 1 US Dollar. The base index rate for US CPI will be on the same basis as for Thai CPI.

Aside from the TAM as outlined above, modifications of some other non-price issues that will enhance the finance ability of all seven IPP projects, e.g., equity ownership structure, commercial operation date, etc., were also endorsed.

(2) SPP - Small Power Producer

(a) Background

Electricity Generating Authority of Thailand (EGAT) is a state enterprise entrusted with the national mission of providing the whole country with a firm and efficient power supply by generation and transmitting electric energy to the two distributing authorities and a limited number of direct customers.

During over 26 years of its operation, EGAT has experienced a rapid and robust growth. It has successfully developed and expanded the power system to satisfy the country's rapid economic and social development.

During the past decade, electricity demand in Thailand has increased very rapidly and is anticipated to continue to grow lighter in years ahead. This calls for the exceptionally high capital investments for power expansion annually over the next decade.

In 1992, the Government announced the policy of state enterprise privatization and encouraging more private sector participation in power development, for reasons of capital requirements, technology transfer, management know-how, private sector ingenuity, and efficiency. This will also encourage more competition in the choice of technology and plant location, and thus, reducing construction costs and arriving at an electricity tariff that will benefit consumers the most.

Apart from the Government's policy to encourage more private sector participation in power development in the forms of Independent Power Producer, the National Energy Policy Council has considered that electricity generation from non-conventional energy, waste or residual fuels on co-generation increases efficiency in the use of primary energy and by-product energy sources, and helps to reduce the financial burden of the public sector with respect to investment in electricity generation and distribution. The Council therefore, in the second meeting of the National Energy Policy

Council dated 12 March 1992 has drawn up the regulations for the purchase of electricity from Small Power Producers which can be summarized as follows :

(b) Definition

"Small Power Producer" (SPP) means: any private, government and state enterprise, which produces electricity using the specified processes and supplies electricity to a Power Utility.

"Power Utility" (PU) means: the Electricity Generating Authority of Thailand (EGAT), the Metropolitan Electricity Authority (MEA), and/or the Provincial Electricity Authority (PEA).

"Regulations for Synchronization of Generators to the System of a Power Utility" means: regulations that govern synchronization of generators to the system of a Power Utility prescribed in the announcement offering to purchase electricity during each purchasing period.

(c) Characteristic of qualified SPP

Power Utility (PU) will purchase electricity from any SPP who has the following qualifying electricity generation processes:

(1) Electricity generation using non-conventional energy such as wind, solar and mini hydro energy (but excluding generation using petroleum, natural gas, coal and nuclear energy).

(2) Electricity generation using the following fuels:

(a) Waste or residues from agricultural activities or from industrial production processes.

(b) Products derived from waste and residues from agricultural and industrial production processes.

(c) Garbage (e.g. municipal waste).

(d) Dendrothermal sources (e.g. tree plantations).

Any SPP using the above fuels may use commercial fuels such as petroleum, natural gas and coal as supplementary fuels provided that thermal energy produced by such supplementary fuels each year does not exceed 25% of the total thermal energy used in electricity generation in that particular year.

(3) Electricity generation by co-generation using any types of fuels that meet the following requirements for power generation.

(a) The thermal energy to be used in thermal process other than electricity generation must be no less than 10% of the total energy production.

(b) The total efficiency must not be less than 45%.

(d) Type of contract

There are two types of contract, which are

(1) Non-firm contract

(a) The term of contract does not exceed 5 years.

(b) The contracted capacity is unspecified.

(2) Firm contract

(a) The term of contract exceeds 5 years .

(b) The contracted capacity must be specified.

(c) The total hours of electricity production supplied must be no less than 7,008 hours per year. For the electricity generating using renewable energy, the annual hours must be no less than 4,672 hours per year.

(e) Maximum capacity to be purchased from each SPP

The maximum capacity is purchased from each SPP is 60 MW for normal case 90 MW for special case if required by the system.

(f) Purchase Prices

Purchase prices are specified in "the EGAT's Announcement on Purchase Price for Power Supplied by SPPs" for each purchasing periods. The purchase prices regarding to the latest announcement dated 5 November 1997 are as follows:

(1) Purchase prices for Firm contract

(a) Capacity Payment (CPo)

Table G.1. Capacity Payment for Firm Contract by EGAT.

Term of contract (N)	Capacity Payment (Baht/Kw/month)		
	Natural Gas	Fuel Oil/Other	Coal
5 yrs < N <= 10 yrs	164	203	229
10 yrs < N <= 15 yrs	224	253	285
15 yrs < N <= 20 yrs	227	281	317
20 yrs < N <= 25 yrs	302	374	422

(b) Energy Payment (EPo)

Table G.2. Energy Payment for Firm Contract by EGAT

Types of Fuel	EP (Baht/ Kwh)
Natural Gas	0.85
Fuel Oil / Others	0.71
Coal	0.62

Note: These price can be adjusted depending on the average dollar exchange rate of the buying and selling rate made via telegram on the last day of month t that the commercial banks apply to customers as published by the Bank of Thailand (Baht/U.S.Dollals)

(2) Purchase prices for Non-Firm contract.

(a) Capacity Payment

There shall be no capacity payment

(b) Energy Payment (EP)

EP = 0.87 Baht / kWh, the rates of energy payment will be adjusted when the cost of fuel oil purchased by EGAT changes by more than 0.05 Baht-Litre from the base price (2.7681 Baht/Litre)

(g) Power Purchase from SPP at present

(1) Only the electricity generated from Non-Conventional Energy, Resident Fuel, Waste, Garbage or Wood Chips can apply for now (For details be referred to Attachment No.4 in the Regulation)

(2) Application form is available at Domestic Power Purchase Division, Electricity Generating Authority of Thailand, Bang Krui, Nonthaburi 11130, Thailand Te1.436-8510

APPENDIX H

INCINERATION PLANT WITH MANY SIZES OF INCINERATOR CAPACITY

Table H.1. Case 1: Incinerator with 150 Tons/Day Capacity for the First Three Year and Additional 150 Tons/Day for the Next Seven Years.

(unit:tons/day)

Year	Volume for incinerated	Capacity	Incineration			Shortage Capacity (per year)	Excess Capacity (per year)	Cost of land for landfill for	
			waste amount (85.66%)	Reduce (85%)	Residue (15%)			residue	waste from shortage capacity
2001	185.48	150.00	150.00	127.50	22.50	12,950	-	5,988,401	56,656,483
2002	196.52	150.00	150.00	127.50	22.50	16,980	-	5,988,401	74,288,497
2003	207.57	150.00	150.00	127.50	22.50	21,014	-	5,988,401	91,934,189
2004	218.79	300.00	218.79	185.97	32.82	-	29,641	8,734,792	-
2005	230.20	300.00	230.20	195.67	34.53	-	25,476	9,190,307	-
2006	241.42	300.00	241.42	205.21	36.21	-	21,380	9,638,297	-
2007	252.65	300.00	252.65	214.75	37.90	-	17,284	10,086,288	-
2008	263.70	300.00	263.70	224.14	39.55	-	13,251	10,527,439	-
2009	274.75	300.00	274.75	233.53	41.21	-	9,218	10,968,590	-
2010	285.44	300.00	285.44	242.62	42.82	-	5,316	11,395,378	-
per day	**2,357**	**2,550**	**2,217**	**1,884**	**333**	-	-	-	-
per year	**860,128**	**930,750**	**809,184**	**687,807**	**121,378**	**50,944**	**121,566**	**88,506,295**	**222,879,168**

Note:
1. The volume of residue 1 ton requires 0.16667 m2 for landfill
2. The volume of waste from shortage capacity 1 ton requires 1 m2/ton for landfill
3. Average estimated price of land in Rajburana is 17,500 Baht/Wah2 (Appendix E)

Table H.2. Case 1: Cost Estimation for Incinerator with 150 Tons/Day Capacity for the First Three Years and Additional 150 Tons/Day for the Next Seven Years.

(million Baht)

Cost \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Capacity	-	**150**	**150**	**150**	**300**	**300**	**300**	**300**	**300**	**300**	**300**
1. Land Cost for											
- plant construction	70.00										
- landfill for											
- residue	88.51										
- waste from shortage capacity	222.88										
Total Land Cost	381.39										
2. Construction cost											
- Mechanical & Electrical Works											
- Fixed Cost 1/	703.60										
- Variable Cost 2/	280.20			280.20							
- Building 3/	1,074.80										
Total Construction Cost	2,058.60										
3. Operating Cost (annual) 4/	41.17	41.17	41.17	41.17	46.78	46.78	46.78	46.78	46.78	46.78	46.78
Total Cost	2,481.16	41.17	41.17	321.37	46.78	46.78	46.78	46.78	46.78	46.78	46.78
Net Present Value 5/	**3,005.63**										

Note: 1/ Fixed Cost, proportionally calculated from 400 tons/day of the 1,000 tons/day capacity of incineration plant (Appendix F)
2/ Variable cost, proportionally calculated from incinerator capacity
3/ Building Construction Cost refers to variable cost, proportionally calculated according to land required (16,000 m^2)
4/ Operating Cost, proportionally calculated from 2% of total construction cost
5/ Yield of Government Bond with 10 years maturity at October 4, 1999, 7.95% (The Thai Bond Dealing Centre)

Table H.3. Case 2: Incinerator with 200 Tons/Day Capacity for Ten Years.

(unit:tons/day)

Year	Volume for incinerated	Capacity	Incineration			Shortage Capacity (per year)	Excess Capacity (per year)	Cost of land for landfill for	
			waste amount (85.66%)	Reduce (85%)	Residue (15%)			residue	waste from shortage capacity
2001	185.48	200.00	185.48	157.66	27.82	0	5,300	7,404,841	0
2002	196.52	200.00	196.52	167.04	29.48	0	1,270	7,845,651	0
2003	207.57	200.00	200.00	170.00	30.00	2,764	0	7,984,535	12,090,439
2004	218.79	200.00	200.00	170.00	30.00	6,859	0	7,984,535	30,009,708
2005	230.20	200.00	200.00	170.00	30.00	11,024	0	7,984,535	48,229,911
2006	241.42	200.00	200.00	170.00	30.00	15,120	0	7,984,535	66,149,180
2007	252.65	200.00	200.00	170.00	30.00	19,216	0	7,984,535	84,068,449
2008	263.70	200.00	200.00	170.00	30.00	23,249	0	7,984,535	101,714,141
2009	274.75	200.00	200.00	170.00	30.00	27,282	0	7,984,535	119,359,834
2010	285.44	200.00	200.00	170.00	30.00	31,184	0	7,984,535	136,431,015
per day	**2,357**	**2,000**	**1,982**	**1,685**	**297**	-	-	-	-
per year	**860,128**	**730,000**	**723,430**	**614,916**	**108,515**	**136,698**	**6,570**	**79,126,769**	**598,052,676**

Note:

1. The volume of residue 1 ton requires 0.16667 m2 for landfill
2. The volume of waste from shortage capacity 1 ton requires 1 m2/ton for landfill
3. Average estimated price of land in Rajburana is 17,500 Baht/Wah2 (Appendix E)

Table H.4. Case 2: Cost Estimation for Incinerator with 200 Tons/Day Capacity for Ten Years.

(million Baht)

Cost \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Capacity	-	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
1. Land Cost for											
- plant construction	70.00										
- landfill for											
- residue	79.13										
- waste from shortage capacity	598.05										
Total Land Cost	747.18										
2. Construction cost											
- Mechanical & Electrical Works											
- Fixed Cost 1/	703.60										
- Variable Cost 2/	373.60										
- Building 3/	1,074.80										
Total Construction Cost	2,152.00										
3. Operating Cost (annual) 4/	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04
Total Cost	2,942.22	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04
Net Present Value 5/	**3,231.67**										

Note: 1/ Fixed Cost, proportionally calculated from 400 tons/day of the 1,000 tons/day capacity of incineration plant (Appendix F)

2/ Variable cost, proportionally calculated from incinerator capacity

3/ Building Construction Cost refers to variable cost, proportionally calculated according to land required (16,000 m^2)

4/ Operating Cost, proportionally calculated from 2% of total construction cost

5/ Yield of Government Bond with 10 years maturity at October 4, 1999, 7.95% (The Thai Bond Dealing Centre)

Table H.5. Case 3: Incinerator with 200 Tons/Day Capacity for the First Six Years and Additional 150 Tons/Day for the Next Four Years.

(unit:tons/day)

Year	Volume for incinerated	Capacity	Incineration			Shortage	Excess	Cost of land for landfill for	
			waste amount (85.66%)	Reduce (85%)	Residue (15%)	Capacity (per year)	Capacity (per year)	residue	waste from shortage capacity
2001	185.48	200.00	185.48	157.66	27.82	0	5,300	7,404,841	0
2002	196.52	200.00	196.52	167.04	29.48	0	1,270	7,845,651	0
2003	207.57	200.00	200.00	170.00	30.00	2,764	0	7,984,535	12,090,439
2004	218.79	200.00	200.00	170.00	30.00	6,859	0	7,984,535	30,009,708
2005	230.20	200.00	200.00	170.00	30.00	11,024	0	7,984,535	48,229,911
2006	241.42	200.00	200.00	170.00	30.00	15,120	0	7,984,535	66,149,180
2007	252.65	350.00	252.65	214.75	37.90	0	35,534	10,086,288	0
2008	263.70	350.00	263.70	224.14	39.55	0	31,501	10,527,439	0
2009	274.75	350.00	274.75	233.53	41.21	0	27,468	10,968,590	0
2010	285.44	350.00	285.44	242.62	42.82	0	23,566	11,395,378	0
per day	**2,357**	**2,600**	**2,259**	**1,920**	**339**	-	-	-	-
per year	**860,128**	**949,000**	**824,361**	**700,707**	**123,654**	**35,767**	**124,639**	**90,166,326**	**156,479,238**

Note:
1. The volume of residue 1 ton requires 0.16667 m2 for landfill
2. The volume of waste from shortage capacity 1 ton requires 1 m2/ton for landfill
3. Average estimated price of land in Rajburana is 17,500 Baht/Wah2 (Appendix E)

Table H.6. Case 3: Cost Estimation for Incinerator with 200 Tons/Day Capacity for the First Six Years and Additional 150 Tons/Day for the Next Four Years.

(million Baht)

Cost \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Capacity	**-**	**200**	**200**	**200**	**200**	**200**	**200**	**350**	**350**	**350**	**350**
1. Land Cost for											
- plant construction	70.00										
- landfill for											
- residue	90.17										
- waste from shortage capacity	156.48										
Total Land Cost	316.65										
2. Construction cost											
- Mechanical & Electrical Works											
- Fixed Cost 1/	703.60										
- Variable Cost 2/	373.60						280.20				
- Building 3/	1,074.80										
Total Construction Cost	2,152.00										
3. Operating Cost (annual) 4/	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04
Total Cost	2,511.69	43.04	43.04	43.04	43.04	43.04	323.24	43.04	43.04	43.04	43.04
Net Present Value 5/	**2,993.48**										

Note: 1/ Fixed Cost, proportionally calculated from 400 tons/day of the 1,000 tons/day capacity of incineration plant (Appendix F)
2/ Variable cost, proportionally calculated from incinerator capacity
3/ Building Construction Cost refers to variable cost, proportionally calculated according to land required (16,000 m^2)
4/ Operating Cost, proportionally calculated from 2% of total construction cost
5/ Yield of Government Bond with 10 years maturity at October 4, 1999, 7.95% (The Thai Bond Dealing Centre)

Table H.7. Case 4: Incinerator with 250 Tons/Day Capacity for Ten Years.

(unit:tons/day)

Year	Volume for incinerated	Capacity	Incineration			Shortage Capacity (per year)	Excess Capacity (per year)	Cost of land for landfill for	
			waste amount (85.66%)	Reduce (85%)	Residue (15%)			residue	waste from shortage capacity
2001	185.48	250.00	185.48	157.66	27.82	0	23,549.95	7,404,841	0
2002	196.52	250.00	196.52	167.04	29.48	0	19,519.77	7,845,651	0
2003	207.57	250.00	207.57	176.44	31.14	0	15,486.47	8,286,802	0
2004	218.79	250.00	218.79	185.97	32.82	0	11,390.64	8,734,792	0
2005	230.20	250.00	230.20	195.67	34.53	0	7,226.02	9,190,307	0
2006	241.42	250.00	241.42	205.21	36.21	0	3,130.19	9,638,297	0
2007	252.65	250.00	250.00	212.50	37.50	965.65	-	9,980,668	4,224,699
2008	263.70	250.00	250.00	212.50	37.50	4,998.95	-	9,980,668	21,870,391
2009	274.75	250.00	250.00	212.50	37.50	9,032.25	-	9,980,668	39,516,084
2010	285.44	250.00	250.00	212.50	37.50	12,934.23	-	9,980,668	56,587,265
per day	**2,357**	**2,500**	**2,280**	**1,938**	**342**	-	-	-	-
per year	**860,128**	**912,500**	**832,197**	**707,367**	**124,830**	**27,931**	**80,303**	**91,023,363**	**122,198,439**

Note:
1. The volume of residue 1 ton requires 0.16667 m2 for landfill
2. The volume of waste from shortage capacity 1 ton requires 1 m2/ton for landfill
3. Average estimated price of land in Rajburana is 17,500 Baht/Wah2 (Appendix E)

Table H.8. Case 4: The Cost Estimation for Incinerator with 250 Tons/Day Capacity for Ten Years.

(million Baht)

Cost \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Capacity	-	**250**	**250**	**250**	**250**	**250**	**250**	**250**	**250**	**250**	**250**
1. Land Cost for											
- plant construction	70.00										
- landfill for											
- residue	91.02										
- waste from shortage capacity	122.20										
Total Land Cost	283.22										
2. Construction cost											
- Mechanical & Electrical Works											
- Fixed Cost 1/	703.60										
- Variable Cost 2/	467.00										
- Building 3/	1,074.80										
Total Construction Cost	2,245.40										
3. Operating Cost (annual) 4/	44.91	44.91	44.91	44.91	44.91	44.91	44.91	44.91	44.91	44.91	44.91
Total Cost	2,573.53	44.91	44.91	44.91	44.91	44.91	44.91	44.91	44.91	44.91	44.91
Net Present Value 5/	**2,875.56**										

Note: 1/ Fixed Cost, proportionally calculated from 400 tons/day of the 1,000 tons/day capacity of incineration plant (Appendix F)

2/ Variable cost, proportionally calculated from incinerator capacity

3/ Building Construction Cost refers to variable cost, proportionally calculated according to land required (16,000 m^2)

4/ Operating Cost, proportionally calculated from 2% of total construction cost

5/ Yield of Government Bond with 10 years maturity at October 4, 1999, 7.95% (The Thai Bond Dealing Centre)

Table H.9. Case 5: Incinerator with 250 Tons/Day Capacity for the First Six Years and Additional 150 Tons/Day for the Next Four Years.

(unit:tons/day)

Year	Volume for incinerated	Capacity	Incineration			Shortage	Excess	Cost of land for landfill for	
			waste amount (85.66%)	Reduce (85%)	Residue (15%)	Capacity (per year)	Capacity (per year)	residue	waste from shortage capacity
2001	185.48	250.00	185.48	157.66	27.82	0	23,549.95	7,404,841	0
2002	196.52	250.00	196.52	167.04	29.48	0	19,519.77	7,845,651	0
2003	207.57	250.00	207.57	176.44	31.14	0	15,486.47	8,286,802	0
2004	218.79	250.00	218.79	185.97	32.82	0	11,390.64	8,734,792	0
2005	230.20	250.00	230.20	195.67	34.53	0	7,226.02	9,190,307	0
2006	241.42	250.00	241.42	205.21	36.21	0	3,130.19	9,638,297	0
2007	252.65	400.00	252.65	214.75	37.90	0	53,784.35	10,086,288	0
2008	263.70	400.00	263.70	224.14	39.55	0	49,751.05	10,527,439	0
2009	274.75	400.00	274.75	233.53	41.21	0	45,717.75	10,968,590	0
2010	285.44	400.00	285.44	242.62	42.82	0	41,815.77	11,395,378	0
per day	**2,357**	**3,100**	**2,357**	**2,003**	**353**	-	-	-	-
per year	**860,128**	**1,131,500**	**860,128**	**731,109**	**129,019**	**0**	**271,372**	**94,078,385**	**0**

Note:
1. The volume of residue 1 ton requires 0.16667 m2 for landfill
2. The volume of waste from shortage capacity 1 ton requires 1 m2/ton for landfill
3. Average estimated price of land in Rajburana is 17,500 Baht/Wah2 (Appendix E)

Table H.10. Case 5: Cost Estimation for Incinerator with 250 Tons/Day Capacity for the First Six Years and Additional 150 Tons/Day for the Next Four Years.

(million Baht)

Cost \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Capacity	-	**250**	**250**	**250**	**250**	**250**	**250**	**400**	**400**	**400**	**400**
1. Land Cost for											
- plant construction	70.00										
- landfill for											
- residue	94.08										
- waste from shortage capacity	-										
Total Land Cost	164.08										
2. Construction cost											
- Mechanical & Electrical Works											
- Fixed Cost 1/	703.60										
- Variable Cost 2/	467.00						280.20				
- Building 3/	1,074.80										
Total Construction Cost	2,245.40										
3. Operating Cost (annual) 4/	44.91	44.91	44.91	44.91	44.91	44.91	50.51	50.51	50.51	50.51	50.51
Total Cost	2,454.39	44.91	44.91	44.91	44.91	44.91	330.71	50.51	50.51	50.51	50.51
Net Present Value 5/	**2,948.76**										

Note: 1/ Fixed Cost, proportionally calculated from 400 tons/day of the 1,000 tons/day capacity of incineration plant (Appendix F)

2/ Variable cost, proportionally calculated from incinerator capacity

3/ Building Construction Cost refers to variable cost, proportionally calculated according to land required (16,000 m^2)

4/ Operating Cost, proportionally calculated from 2% of total construction cost

5/ Yield of Government Bond with 10 years maturity at October 4, 1999, 7.95% (The Thai Bond Dealing Centre)

Table H.11. Case 6: Incinerator with 300 Tons/Day Capacity for Ten Years.

(unit:tons/day)

Year	Volume for incinerated	Capacity	Incineration			Shortage Capacity (per year)	Excess Capacity (per year)	Cost of land for landfill for	
			waste amount (85.66%)	Reduce (85%)	Residue (15%)			residue	waste from shortage capacity
2001	185.48	300.00	185.48	157.66	27.82	0	41,799.95	7,404,841	0
2002	196.52	300.00	196.52	167.04	29.48	0	37,769.77	7,845,651	0
2003	207.57	300.00	207.57	176.44	31.14	0	33,736.47	8,286,802	0
2004	218.79	300.00	218.79	185.97	32.82	0	29,640.64	8,734,792	0
2005	230.20	300.00	230.20	195.67	34.53	0	25,476.02	9,190,307	0
2006	241.42	300.00	241.42	205.21	36.21	0	21,380.19	9,638,297	0
2007	252.65	300.00	252.65	214.75	37.90	0	17,284.35	10,086,288	0
2008	263.70	300.00	263.70	224.14	39.55	0	13,251.05	10,527,439	0
2009	274.75	300.00	274.75	233.53	41.21	0	9,217.75	10,968,590	0
2010	285.44	300.00	285.44	242.62	42.82	0	5,315.77	11,395,378	0
per day	**2,357**	**3,000**	**2,357**	**2,003**	**353**	-	-	-	-
per year	**860,128**	**1,095,000**	**860,128**	731,109	**129,019**	**0**	**234,872**	**94,078,385**	**0**

Note:

1. The volume of residue 1 ton requires 0.16667 m2 for landfill
2. The volume of waste from shortage capacity 1 ton requires 1 m2/ton for landfill
3. Average estimated price of land in Rajburana is 17,500 Baht/Wah2 (Appendix E)

Table H.12. Case 6: Cost Estimation for Incinerator with 300 Tons/Day Capacity for Ten Years.

(million Baht)

Cost \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Capacity	-	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**
1. Land Cost for											
- plant construction	70.00										
- landfill for											
- residue	94.08										
- waste from shortage capacity	-										
Total Land Cost	164.08										
2. Construction cost											
- Mechanical & Electrical Works											
- Fixed Cost 1/	703.60										
- Variable Cost 2/	560.40										
- Building 3/	1,074.80										
Total Construction Cost	2,338.80										
3. Operating Cost (annual) 4/	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78
Total Cost	2,549.66	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78
Net Present Value 5/	**2,864.27**										

Note: 1/ Fixed Cost, proportionally calculated from 400 tons/day of the 1,000 tons/day capacity of incineration plant (Appendix F)

2/ Variable cost, proportionally calculated from incinerator capacity

3/ Building Construction Cost refers to variable cost, proportionally calculated according to land required (16,000 m^2)

4/ Operating Cost, proportionally calculated from 2% of total construction cost

5/ Yield of Government Bond with 10 years maturity at October 4, 1999, 7.95% (The Thai Bond Dealing Centre)

APPENDIX I

EMISSION STANDARD IN THAILAND

Emission Standards in Thailand

Table I.1. The Emission Standards in Thailand.

Substances /Sources	Standard	Values
1. boiler & Furnace		
■ Heavy oil as fuel	300 mg/Nm	
■ Coal as fuel	400 mg/Nm	
■ Other fuel	400 mg/Nm	
2. Antonomy	20 mg/Nm	
3. Arenic	20 mg/Nm	
4. Copper	30 mg/Nm	
5. Lead	30 mg/Nm	
6. Chlorine	30 mg/Nm	
7. Hydrogen Cholride	200 mg/Nm	
8. Mercury	3 mg/Nm	
9. Carbonmonoxide	1,000 mg/Nm	or 870 ppm
10. Sulfurdioxide	100 mg/Nm	or 25 ppm
11. Hydrogen Sulphide	140 mg/Nm	or 100 ppm
12. Sulfuredioxide	1,300 mg/Nm	or 500 ppm
13. Oxides of Nitrogen		
■ Coal as fuel	940 mg/Nm	or 500 ppm
■ Other fuel	470 mg/Nm	or 250 ppm
14 Xylene	870 mg/Nm	or 200 ppm

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