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Feasibility Assessment of RDF Utilization for Power Generation in Thailand

Nakorn Tippayawong*, Saiwasan Vichadee

Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University,
Chiang Mai 50200 Thailand
Tel.: +66-5394-4146, Fax: +66-5394-4145, E-mail: n.tippayawong@yahoo.com

Abstract

Cost effective and environmentally acceptable management and disposal of solid waste is needed in modern society. Solid waste can be an important renewable energy resource. The present paper focuses on an integrated waste management and power generation for Chiang Mai, Thailand. Using realistic estimates of waste quantity and composition, waste-to-energy conversion plant using refuse-derived fuel with appropriate incineration technology was proposed. An economic feasibility survey has been performed to evaluate benefits of the project and to attract potential investors in the future. Capacity analysis suggested that a project with power generation capacity up to three MW can be developed and such a project is economically feasible with tolerance to fluctuation in capital cost, tipping fee and recycled material price.

Keywords: Incineration, MSW, RDF, Renewable Energy, WTE

1. Introduction

All over the world, problem of municipal solid waste (MSW) is serious and is growing in importance with population, industrialization and urbanization. MSW is mainly generated from residential and commercial refuse in vast quantity. Collection and disposal of MSW in an environmentally safe manner is vital to a community. Solid waste management has become a major concern and one of the most important environmental and political issuein modern society. Disposal of MSW is problematic in many areas largely because landfill space is becoming scarce and public concern with environmental problems is rising. Development and implementation of methods for cost effective and environmentally acceptable disposal of solid waste are urgently required. In most countries, emphasis has been placed on utilizing solid waste for the generation of electricity as an attractive alternative to landfills. Waste-to-energy (WTE) by combustion in modern facilities with adequate and careful environmental monitoring has been shown to be a safe and cost effective technology. WTE conversion has a worldwide adoption and is becoming popular in Asia. It is also realized that WTE facilities contribute to a positive cash flow in areas where tipping fees are high and landfill space is limited. Municipal authorities particularly like the concept because it greatly extends landfill life through a great reduction in volume and ameliorates the final waste disposal into landfills.

For an integrated system approach, one of the options advocated by MSW management planners and government regulations is the recycling and recovery of material as well as energy through production of a refuse derived fuel (RDF), instead of conventional mass burning [Di Maria and Pavesi, 2006]. RDF production process starts with the separation and sorting of MSW to remove recyclable or potentially hazardous materials from the waste stream. The remaining combustible material is then crushed or grinded and conveyed to a dryer to remove excess moisture by steam or hot air. It is finally compacted in the form of pellets. RDF has several benefits over untreated MSW. The main advantages are the higher heating value, the homogeneity of physico-chemical composition, the ease of storage, handling and transportation, the lower pollutant emissions and a reduced excess air requirement during combustion [Chang et al., 1998; Caputo and Pelagagge, 2002a].

The present investigation focuses on an integrated waste management and power generation project to be established in Chiang Mai, Thailand using RDF technology. Economic feasibility and financial risk of the project proposal is evaluated by carrying out a capacity analysis. Investment costs, net present value, benefit-cost ratio and internal rate of return are evaluated and used as indices for project evaluation. Sensitivity analysis of equipment costs, tipping fee and market price of produced goods such as recovered materials are also performed.

2. Current MSW Management Practices in Thailand

Thailand's rapid growth in the past several years has led to a pattern of high consumption. Rampant consumerism has meant that waste generation has been greater than the provision made for it. According to the Pollution Control Department (2003), total solid waste throughout the country was 13.5 million tons in 1997 and increased to 13.8 and 14.4 million tons in 2000 and 2003, respectively. The per capita generation of MSW in Thailand was approximately 0.5 – 1.0 kg/day, with average value of 0.65 kg/day. The increasing trend in quantity generated is expected at a rate about 1.0-2.0% per year. The increase in domestic MSW has placed a tremendous pressure on the government and local authorities to manage it effectively. Thailand's present solid waste management strategy focuses on bulk collection and mass disposal. Thai government is trying to implement an integrated waste management system that includes waste sorting, composting, incineration and, to a smaller extent, landfilling.

Recently, Thai government set up national policy to (i) improve solid waste disposal and processing procedures; (ii) support and encourage proper solid waste separation; (iii) encourage recycling and reuse; and (iv) support local authority to build up capacity for waste management. Currently, almost two third of collected waste in Thailand is dumped or, in some areas, burnt openly. About one third of collected waste is disposed of by landfilling. This is highly disputed in many areas because of the environmental problems related to its use as well as its growing cost at the local level. Composting practice is still limited in Thailand, in spite of its simplicity and low capital requirements. Most organic waste is not utilized properly. With respect to MSW incineration, it is not yet firmly established in the country. There are only two municipal waste incineration plants operational in Thailand, situated on the islands of Phuket and Samui in the South. Design capacities are reported to be 250 and 140 tons per day, respectively. Other solid waste incineration plants are much smaller in size and can be found in industrial estates, located near the eastern coast of the country, with capacity ranging from only 7 to 20 tons per day.

Other possible technology options for WTE include (a) anaerobic digestion with biogas power plant, (b) sanitary landfill with landfill gas power plant, and (c) RDF incineration power plant. They are considered as new technologies. So, these technologies have to be imported from abroad. The first two are under demonstration phase in Thailand at the moment [Department of Energy Development and Promotion, 2003] whereas the last one has not yet been considered.

3. Proposed RDF/WTE Facility for Chiang Mai

A case study has been conducted for Chiang Mai,the second largest city in Thailand. Chiang Mai accommodates government offices, shopping complexes, medical, agricultural and educational institutions, industrial units and residential areas. It is also a major tourist destination. The city has a population of about 400,000 with about 3 million visitors a year. The current MSW collected in Chiang Mai is approximately 400 tons/day. The waste collection is normally carried out by the Municipality and local authorities. The composition of the Chiang Mai MSW is shown in Table 1, according to the Pollution Control Department. Daily MSW generation is assumed to be consistent and able to supply uniformly constant raw materials for RDF throughout the year. The location for the RDF/WTE station is designated to be on the existing dumping/landfill site in Doi Tao, about 7 km from the main highway and 75 km from Chiang Mai city centre (shown in Figure 1). The proposed site is a rural area. The site occupies over 20 acres and is surrounded by uncultivated land. A number of manmade water reservoirs are available nearby for use. The place is well connected by a network of roads. Furthermore, the site has already passed an environmental impact analysis as well as a public and stake holder debate concerning MSW disposal and management.

WTE facilities are based on RDF and incineration technology. The whole amount (400 tons/day) of MSW goes through an RDF production line. This is accomplished through successive treatment stages of screening, shredding, size reduction, classification, separation, drying, densification, and storage. Hand picking was extensively used as the method of separation rather than the more expensive automated methods mainly because of low labor cost. The approximately 180 tons of RDF can be produced per day, after removal of recyclables, non-combustibles, inerts and moisture.

The RDF is composed of paper and paperboard, plastics, rubber and leather, textiles and woody matter. The chemical compotion of each RDF component has been evaluated according to Tillman (1991) and listed in Table 2. Using Dulong's empirical formula, the RDF's mean heating value is estimated to be 13 MJ/kg. The RDF is assumed to be produced in a moderate processing plant.

The choice of the combustion technology depends upon the properties of raw material and availability of expertise. The stoker fired, grate combustor is generally accepted to be the most experienced and mature technology for mass burning. The same technology is also well suited to combust the flow of RDF resulted from light mechanical treatment in this proposed project [……]. This is the appropriate combustion technology for the local companies and skilled labors can handle with no major difficulty. It is simple to manage, effective for RDF incineration, and yet suitably priced. The feedstock obtained is fed into the stoker fired boiler to generate high pressure steam. The steam is piped directly to power impulse steam turbo-generators. Exhaust from the stack is to be monitored and the data used to adjust the excess air in the furnace for optimal operation. To be in compliance with Thailand national ambient air quality standard restrictions, air pollution control devices such as dry, semi-dry and wet scrubbers to remove acid gas, heavy metals, dioxin and furans, bag filters and electrostatic precipitator to remove large and small particulate matter as well as dust, are employed. The plant also includes other logistical facilities such as the weighing scale, administration building, workshop, ash removal and disposal equipment.

4. Economic Feasibility Analysis

Based on the availability of the RDF, its composition and total heat capacity, up to 25 MW_{th} may be generated. For a realistic possibility, power production capacity of 1-10 MW_e is considered. It is useful to estimate the costs related to its realization and management. The proposed project will be financed wholly from private investment, having a firm power purchase agreement with the Electricity Generating Authority of Thailand (EGAT), the national electricity generator and sole distributor. The plant factor is assumed to be 80% (7,008 hrs per year). In this analysis, exchange rate was referred to baht/$ = 38.0:1.0, and baht/Euro = 48.0:1.0, as of February 2005. Project duration is set to 10 years, equal to MSW management contract with local authority.

The complete cost estimation of the RDF/WTE facilities is the sum of two separate facilities; the RDF processing plant and the RDF incineration and power generation plant. The cost of each plant is included into two main components – total capital investment, and operation and maintenance cost. Total capital investment is derived from the sum of fixed direct and indirect capital investment. Direct cost involves costs for main machineries and equipments, their auxiliaries and installation (piping, insulation, painting, electrical equipment and materials, grid connection, power and lighting, instrumentation and controls, process buildings and structures, site development; services utilities, and provision of water, air, firefighting services); and land lease. Indirect cost includes engineering and supervision; construction expense; contractor's fee; and contingency. Normally, indirect cost is estimated to be about 10% of the direct investment cost. Meanwhile, operation and maintenance cost is generally divided into fixed operating costs, variable operating costs, and general expenses. The items of the fixed operating costs are maintenance, operating labor, supervision, plant overheads, capital charges or interest payment, laboratory expenses, insurance, and local taxes. Variable operating cost items include raw materials, utilities, miscellaneous operating materials, and transportation. General expenses are administrative expenses, distribution and marketing expenses, research and development expenses, and gross earning expenses. Cost information was provided by Elektrowatt-Ekono Company and from reference sources [Caputo and Pelagagge, 2002b; Choy et al., 2004; Kanjanarerk, 2002] or estimated as reasonable fraction of total cost.

Revenues of the RDF/WTE power station come mainly from the sale of produced electricity, recycled materials, as well as from MSW tipping fee. According to EGAT [Energy Policy and Planning Office, 2004], electricity energy and capacity payments are calculated to be 1.62 baht ($0.04) per kWh and 208.32 baht ($5.48) per kW month, respectively. Recycled materials may be sold as scrap if they are inorganic matter (glass: 5 baht ($0.13) per kg; iron: 4 baht ($0.11) per kg; aluminium: 25 baht ($0.66) per kg). MSW tipping fee at the gate is charged at 300 baht ($7.90) per ton. Annual cash flow is computed by subtracting annual operating costs from the revenues. It should be noted that the left over of sorted MSW is land filled through normal practice and no composting is involved in this proposed facility.

For economic feasibility analysis, net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR) are evaluated and used as indices for project evaluation:

$$NPV = \sum_{t=1}^{10} \left(B_t - C_t\right) \Big/ \left(1 + r\right)^t \tag{1}$$

$$BCR = \sum_{t=1}^{10} B_t \Big/ \left(1 + r\right)^t \Big/ \sum_{t=1}^{10} C_t \Big/ \left(1 + r\right)^t \tag{2}$$

$$\sum_{t=1}^{10} \left(B_t - C_t\right) \Big/ \left(1 + IRR\right)^t = 0 \tag{3}$$

where B_t, C_t are benefits and costs in year t, and r is the discount rate. Different scenarios of projected power production capacity, equipment costs, tipping fee and market price of recovered materials are performed. For different power capacity, cost items are approximated to vary according to the following law of economy of scale:

$$C = C_0 \left(Q / Q_0\right)^{0.6} \tag{4}$$

where C_0 is the cost of the plant having capacity Q_0.

5. Results and Discussion

A power plant with capacity of 1-10 MW_e was considered attractive for private investment in the target area. It was assumed that the plant would receive all 400 tons/day of MSW but process just enough RDF for electricity generation of predetermined megawatt. The rest of MSW was to be disposed of conventionally via landfill method. Cost of transporting MSW to the gate was solely local municipality's responsibility. Cost analysis has been performed for different capacities and the results are shown in Table 3. Increasing capacity will generate more electricity revenue while revenues from tipping fee and recycled material are constant for a fixed amount of MSW. However, larger sized plant and machinery is required. From the cost analysis, it was clear that high initial investment was required to set up a RDF-to-energy plant, however, return on investment may be attractive with sizable annual revenues from tipping fee and sales of electricity and recycled materials. Technology for RDF-to-energy is not currently practiced at this scale in Thailand. The capital cost for imported technology and machinery was therefore high. It is expected that once the country starts practicing at large scale, there will be development of its own indigenous machines and the capital cost will dramatically reduce.

For the present situation, economic feasibility analysis to evaluate the project is carried out and the results are plotted in Figure 2. NPV, BCR and IRR for each capacity are compared for the same intake of MSW. From the projections at the end of the 10th year, it was evident that higher power capacity led to less favorable economic performance, due mainly to high initial cost required. It was found that an increase of power generation from 1 to 10 MW_e caused NPV to change from positive to negative values, reduced BCR from above 1.8 to below 1.2, and decreased IRR from 45% to less than 10%, respectively. Up to 3 MW_e was attractive and economically feasible for investment with current scenario since higher capacities resulted in negative NPV and unacceptable return on investment. Calculated payback period was approximately 3 and 6 years for 1 and 3 MW_e projects, respectively. The costing of electricity generation from each capacity was also carried out and shown in Figure 3. It was clear that electricity cost progressively reduced from 11.5 to 4.1 baht/kWh with an increase in power generation capacity from 1 to 10 MW_e. It was worthwhile to note that this was a conservative estimate as the life of the facilities was expected to expand well above 10 years and performance of the plant based on steam cycle was subject to strong scale effect. Larger plant can achieve higher efficiency and lower investment cost per unit electricity generated. Even through an investment for such a project is found not to be remunerative at larger capacity, it is necessary for a proper waste management policy. At a capacity below an economically feasible three MW_e, only a fraction of MSW will be processed into RDF, leaving a large portion to be managed via landfilling. Hence, full potential for social and environmental benefits from the project will not be realized. Alternative or improved technology with better efficiency may be considered such as dedicated treatment prior to energy recovery, fluidized bed combustion, gasification, etc in order to utilize as much RDF as possible. However, there is still a need to evaluate cost and return on investment of this particular technology which should be attractive either on its own or with support from the government.

Three parameters have been studied in the sensitivity analysis of the proposed RDF-to-energy plant at one MW_e as a case study. They are (i) total capital cost, (ii) recycled material selling price, and (iii) tipping fee. Figure 4 shows the effect of change in these parameters upon investment return. The most influential parameter appeared to be the total capital cost. The total capital cost took into account both fixed direct and indirect costs, including major equipment items, constituting about 90% of initial investment. These major equipment items are normally imported. However, the prices of these equipment items are cheaper if they are provided from India, China or local Thai companies, rather than imported from Europe, USA or Japan. The potential cost savings may be more than 50%. Therefore, if the total capital cost can be halved, the rate of return will increase from 45 to above 70%. It should be emphasized that waste disposal is an activity with high social impact, thus, citizens must contribute adequately. It is likely that the local municipalities and governments will pay a tipping fee for MSW in the future which will affect their residents. A fee assessment is needed to estimate the overall cost. The results shows that fee reduction would abruptly decrease the return on investment in similar fashion to reduction in recyclable material selling price. Better economic performance can be achieved if more revenue is obtained from recyclable materials or electricity selling prices. Probability of such situation can be increased if government support can be obtained. Nonetheless, it was important to point out that social costs and benefits measured in terms of improved quality of life, reduced health and welfare damage, as well as environmental benefits associated with reduced pollution and preserved landfill space were not estimated and included. Should they be taken into consideration and the barriers created from initial investment costs be overcome, the RDF-to-energy will be a feasible solution to MSW management.

6. Conclusions

An extensive economic analysis of an MSW management option has been carried out to evaluate the feasibility of integrating RDF production to RDF-to-energy facilities under current MSW generation in Chiang Mai, Thailand. The economic feasibility of RDF-to-energy plant has been investigated by carrying out a capacity analysis as well as evaluating investment costs, net present value, benefit-cost ratio and internal rate of return. Sensitivity analysis of capital cost, tipping fee and market price of produced goods such as recovered materials has also been performed. The analysis showed that, with technological option considered, up to three MW_e power plant has attractive return on investment. Larger power capacities resulted in negative NPV and unacceptable BCR and IRR. Under this scenario, majority of MSW will still be disposed of in landfills. Hence, environmental benefit is not realized to the full. To gain considerable environmental, social and economic benefits such as reduction of need for new landfill sites, prolonged existing landfill sites, clean air and less underground contamination, lower chance of disease spreading, new business and employment for recycling, government subsidies for the RDF-to-energy project may be offered. These can be in terms of subsidized credits, partial public funding, etc. considering its social relevance in the framework of government waste management policy.

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