論 文 の 内 容 の 要 旨

Abstract of Dissertation

論文題目：**Evaluation of Waste-to-Energy Technology Incorporated into the Integrated Solid Waste Management System in Thailand**

Title of Dissertation **(タイにおける統合的固形廃棄物管理システムに組み込んだ廃棄物エネルギー変換技術の評価)**

氏　名　　タパラクサナコン キテイパン

Name of Author　　**TAPARUGSSANAGORN Kittiphan**

Thailand currently produced about 14.4 million ton/year of the municipal solid waste (MSW), nearly all of which are disposed in landfill. Only 5 disposal sites nationwide truly operate with all the operation practices and environmental controls and conditions expected for a sanitary landfill. The remaining sites incorporate some but not all of these practices and most commonly lack environmental controls. Furthermore, MSW generation would grow 25% by the end of decade. Pollution Control Department (PCD), the national authority that responsible for the MSW management policy and planning, has 2 goals on MSW strategy as:

1. Implementation of feasible and appropriate technical solutions for integrated MSW management focusing on waste-to-energy (WTE) scheme, and
2. Reduction of MSW to be disposed of in landfills in target areas and utilization of MSW as energy generation.

So, Thailand has opportunity to make progress in improving the public health and environment for future generations through better waste management by the large untapped potential of energy recovery from MSW.

To make a resource utilization project by the WTE strategy, incineration technology is developed to perform high-efficiency power generation by reheating the low temperature steam collected from MSW incinerator using petroleum fuel and generate the high temperature steam. Electrical and thermal energy can be utilized from this facility. However, using the combination among landfill, incineration, and composting options for integrated solid waste management (ISWM) system may be necessary for successful waste management. This study addressed the comparative evaluations on the

interrelationships among geographic condition, treatment options, economic impact, environmental impact, social impact, and integration framework and legislation requirement under the life cycle concept.

Comprehensive approach on the project feasibility study for the business opportunity of the WTE in Thailand was adopted in the research. Various sources of data were use in the study. Mass burn incineration, such the simple stoker grate WTE plant, was selected for the evaluation in this research. It is a well proven technology and predominant form of MSW incineration because of its simplicity. However, the MSW-fired power cycles have one of the operation limitations resulted from high corrosiveness of the boiler tube at high temperature and consequently very low electrical generating efficiencies. So, incorporation of the MSW boiler as a bottom cycle into a hybrid combined cycles with natural gas (NG) fired topping gas turbine, where the topping exhaust provides superheating, can substantially improve the electrical efficiency of MSW energy utilization using only conventional technology.

From the study of MSW generation, collection, and management policy in Thailand, it was found that BMA (Bangkok Metropolitan Administration) area could be a representative location of the WTE facility and ISWM system proposed in this research. Project site options for the establishment of MSW incineration plant in this research are selected at: 1) Onnuch transfer station, S1 2) Ladkrabang industrial estate, S2, and 3) Bangpoo industrial estate, S3.

Treatment options in this research covered: 1) Landfilling as business as usual ($Landfill_{bau}$) that accounted only its operation cost, or operation practice improved with the true cost of investment is covered ($Landfill_{truct}$), 2) WTE incineration with options combination of the energy recovery as electricity ($Incineration_{power}$) and heat ($Incineration_{CHP}$), and the combined cycle technology ($Incineration_{HCC}$ and $Incineration_{HybCHP}$), and 3) Composting: for the organic fraction of the waste. Options of ISWM system as 2,600 ton/day capacity are: 1) dispose all 2,600 ton/day in landfill 2) 1,300 ton/day is disposed in landfill and 1,300 ton/day is incinerated 3) 2,600 ton/day is incinerated 4) 1,300 ton/day is incinerated and 1,300 ton/day is composted and 5) 1,300 ton/day of MSW is disposed in landfill and another 1,300 ton/day is composted. Using the combination of the options for ISWM system, landfill situation, incineration system, and project site; 44 alternatives was established.

In the economic feasibility study, discount cash flow (DCF) model with full cost accounting

(FCA) was developed to tackles the planning phase of local ISWM incorporated with WTE technology. The economical beneficial effects of the hybrid combined cycles for WTE incineration in ISWM framework have been confirmed.

For the environmental feasibility study, it was aimed to understand the overall environmental impact of the waste treatment alternatives for municipal solid waste management (MSWM) planning with life cycle assessment (LCA). The result from life cycle impact assessment (LCIA) showed the environmental benefit of implementing the WTE incineration with heat recovery. The study also pointed out the environmental impact from current operation of landfill disposal. Integrated weighting indicator was established for the decision maker, so that the decision makers could base their judgment on the complete view provide by environmental impact assessment from various impact categories.

Public preferences for MSWM alternatives using contingent valuation method (CVM) in Bangkok were conducted as social feasibility study. People's concerns towards MSWM and their relation with the preferences to facilities were analyzed. Questionnaires were used in face-to-face interviews with the residents in Bangkok. A questionnaire was designed based on major concerns of willing to accept (WTA) and willing to pay (WTP) of the proposed ISWM alternatives. Results revealed the considerable preference in incineration with combined cycle technology, and affordability in the combined cycle incineration with heat utilization over the other treatment methods.

Economic, environmental, and social aspects have to be considered to measure the sustainability of project development. Driving forces of the project were examined and decision indicators were identified. Multi-criteria analysis (MCA) technique for comparing and ranking different outcomes that evaluated from non-monetary objectives and indicators was applied. Result from the calculation of sustainability indicator showed that combined cycle incineration with heat utilization alternative gave the optimal performance.

Panel weighting by face-to-face interviews was conducted. Weighting value that reflected durability of the sustainability was based on the qualitative consideration from stakeholder situation. Result showed slightly different weights received from the panel compared with the equal weighting. Increasing weight in economic domain from the panel resulted decreasing in attraction of the ISWM alternatives engaged with incineration. Integrated evaluation combined both optimality and durability provided

final result for sustainable development of the MSWM to the decision maker.

From this study, the following conclusions were withdrawn: The position of Thailand is on the decisive steps to address the unfinished agenda by focusing on MSW reduce and recycling; improving treatment and safe disposal; enhancing the supporting institutional, regulatory, and financing framework; and expanding public and civil society participation.

A framework has been developed to assess impacts, especially economic, social, and environmental impacts of technologies. Research on improving the framework is required, considering on the reduction of uncertainties and expanding of the treatment methods and criteria pollutants for impact assessment. It is recommended that the best available data be used to minimize the discrepancies between the model and reality.

The policy implications of the results presented in this research depend on the aim of policy. The discussion here tasks as a starting point that one aim of the policy is to establish central solid waste disposal facilities with integrated concept of appropriate technology and beneficial utilization of waste such as energy recovery.

In the system studied here, combined cycle incineration with heat utilization alternative gives the most attractive performance. If MSW can replace fossil fuel energy sources, a policy promoting incineration will be success. Application of the methodology in this research may be useful to other developing country in MSWM to utilize the valuable potential as an alternative resource.