Determination of Waste Treatment Fee Pricing Mechanism for Municipal Solid Waste by Mechanical Biological Treatment Method utilizing the Public Private Partnership Model in Thailand

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Abstract — **The participation of the private sector in equity investment and operation of municipal solid waste treatment facilities through the Public-Private Partnership (PPP) model promotes the implementation of sustainable solid waste treatment technologies without creating excessive financial burden in governmental infrastructure investment. The introduction of preset pricing mechanism to regulate potential waste treatment fee structure based on pre-determined project internal rate-of return mitigates multi-party risks, such as the potential developer project losses or the opportunity to profiteer. Research encompasses technical assessment of project requirements for implementation of required technologies, commercial analysis of project capital expenditure (CAPEX), operational expenditure (OPEX) and assessment of revenue streams of the facility. Computer simulation of commercial data computes the case study of a 600 tonne per day MBT facility's first-year waste treatment fee of THB 546.00, THB 709.00 and THB 890.00 based on pre-determined project internal rate of returns of 8.00%, 10.00% and 12.00% respectively. Macroeconomic data influences within pricing mechanism determines long-term effects to facility pricing fee structure to further mitigate project commercial risks.**

Index Terms **— Solid Waste Management, Municipal Solid Waste, Waste Treatment Fee, Mechanical Biological Treatment, Pricing Mechanism, Infrastructure Sector**

I. Introduction

Municipal solid waste (MSW) is defined as unwanted products which have been discarded by households, but can include similar waste products that are discarded from commercial, public areas and offices which are collected by municipal or private haulers for disposal through the waste management system [1].

Current municipal solid waste generation (as of year 2015) in Thailand amounts to 26.85 million tonnes, of which almost 51% (13.53 million tonnes) are disposed improperly such as in waste dumps, 31% (8.34 million tonnes) disposed at lined landfills and 18% (4.94 million tonnes) utilised for recycling activities or energy generation [2]. Most MSW generated is disposed of at one of 106 landfills in operation across Thailand.

In 2015, Thai government announced sustainable municipal solid waste management as National Agenda No. 1, to promote proper, clean and sustainable methods for disposal of municipal solid waste, with the "emphasis on resource recovery wherever possible & energy recovery whenever possible".

This research presents an appropriate waste treatment fee calculation mechanism under the Public-Private Partnership (PPP) model which is transparent, flexible and repeatable that scrutinizes investor profitability within an acceptable project internal rate-of-return (IRR) range, reducing the potential of project developer "profiteering".

The proposed 600 tonne per day Mechanical Biological Treatment (MBT) facility in Bangkok, developed under a 20-year PPP model is utilised as the case study for this research. The pricing mechanism is formulated and validated using the case study's technical and commercial data, with long-term macroeconomic data utilised to forecast external market scenarios over the 20-year operating lifetime of the facility.

A. Mechanical Biological Treatment Concept

The mechanical biological treatment (MBT) concept is defined as the combination of recycling (material recovery) and anaerobic digestion or aerobic waste treatment concepts for the comprehensive treatment of mixed municipal solid waste. In general, a MBT plant consists of mechanised sorting facility, aerobic rotating (or anaerobic) bioreactors, forced-aeration stabilisation air-tunnels, ripening platforms and a sanitary landfill site [3]. In assessing the use of anaerobic digestion in the treatment of solid waste, Braber [4] determined that anaerobic digestion is a viable technology in the production of energy from the organic portion of municipal solid waste, with end product potential in closing the carbon cycle and promoting environmental sustainability. Eichner & Pethig [5] had utilised a general equilibrium model for determination of waste constituents to determine the benefits of material recovery in relation to potential environmental damages and evaluate policy instruments to optimize green waste recovery processes. Fig. I illustrates the technologies utilised under the MBT concept within overall MSW treatment hierarchy.

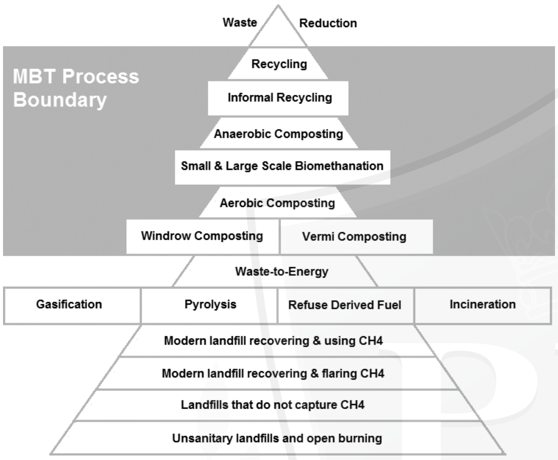

Fig. I. Mechanical biological treatment technology utilisation within the MSW treatment hierarchy [6].

B. Waste Treatment Fee Collection Structure

At present, MSW treatment fee collection from consumers are divided into "flat rate" and "unit-based" payment structures. The "flat rate" concept encompasses lump sum payment for a fixed period of service, usually over an annual period (property or general assessment payment). Advantages of this method include the constant, recurrent revenue generation for the administrative council but may not promote waste reduction initiatives among waste generators due to the lack of economic incentive in this regard, reducing the ability of administrative councils to introduce any improvement to current waste management processes [7]. The "unit-based" concept charges by actual use of service. This promotes waste reduction and recycling through economic incentive without limiting the waste generator's access to the service [8]. Table I lists literature review findings of current national waste fee collection tariff collection method and payment vehicles for selected countries within Asia.

TABLE I

Waste fee collection structure within asia

Country	Income Status	Tariff Method	Payment Vehicle	Ref.
Japan	High Income	Unit-Based	Weight-based	[9]
China	Lower Middle Income	Flat Rate	General tax	[10]
Indonesia	Lower Middle Income	Flat Rate	Direct charge	[11]
Malaysia	Upper Middle Income	Flat Rate	Property Assessment	[12]
Singapore	High Income	Flat Rate	Property Assessment	[13]
Thailand	Lower Middle Income	Flat Rate	Direct Charge	[14]
Bangladesh	Low Income	Flat Rate	Direct Charge	[15]
India	Lower Middle Income	Flat Rate	Property Assessment	[16]
South Korea	High Income	Unit-Based	Weight-based	[17]
Sri Lanka	Lower Middle Income	Flat Rate	Property Assessment	[18]
Philippines	Lower Middle Income	Flat Rate	Direct Charge	[19]

C. Privatization of the Waste Management Sector

In assessing the entry of the private sector into the market, Bel & Warner [20] concluded that while cost savings through privatisation of waste treatment are not systemic, transaction costs are best regulated when contracts are given as complete packages with pre-set market and operating structures. Additionally, oversight and regulation play an important role in optimizing privatisation of services. While solid waste management policies remain incomplete, economic literature shows that current treatment fees for rationalization of investment in waste management technologies remain incorrect.

Turley & Semple [21] stated that private sector's investment and participation in public infrastructure projects must, at the least be able to cover initial principal investment and corresponding interest incurred through project financing either by debt finance or equity finance; with sufficient dividends paid for project involvement.

Zhang [22] had proposed that a project's concession period be sufficient to cover the project developer's equity and debt-financing responsibility while providing sufficient profit to ensure a "win-win" situation between the government and the private sector, with the typical cash flow of a BOT project.

This research is intended to introduce an independent pricing mechanism philosophy that can be considered for determining acceptable MSW treatment fees for Mechanical Biological Treatment (MBT) facilities based on pre-determined project internal rate of return (IRR).

II. Methodology

Research framework divides the study into 5 sections, i.e. (1) determination of MSW characteristics, (2) selection of mechanical biological treatment method, (3) determination of project capital (CAPEX) & operational (OPEX) expenditure and revenue streams, (4) formulation of the waste treatment pricing mechanism, and (5) designing a software to generate MSW treatment fee.

A. Determination of MSW Characteristics

MSW quantitative and qualitative data was conducted at the case study's current waste transfer station utilizing ASTM D5231-92(2008): Standard Test Method for Determination of Composition of Unprocessed Municipal Solid Waste. Further qualitative analysis was conducted on the recovered organic portion for mass and energy balance formulation purposes.

B. Selection of MBT Method

MBT process encompasses the integration of 4 separate waste treatment processes as follows.

a) pre-treatment/volume reduction
b) biological treatment
c) product/quality refining
d) preparation for market

Selection of the treatment process is dependent on project objectives, technological viability, commercial value of intended resources for recovery, and project budget.

C. Determination of Project CAPEX & OPEX

Investment costs for a MBT facility is dependent on several key factors such as plant development size, treatment capacity, location, intended operation life, level of automation, pollution control, intended processes and redundancy requirement. Figure II breakdowns a MBT facility's capital expenditure into 8 separate categories.

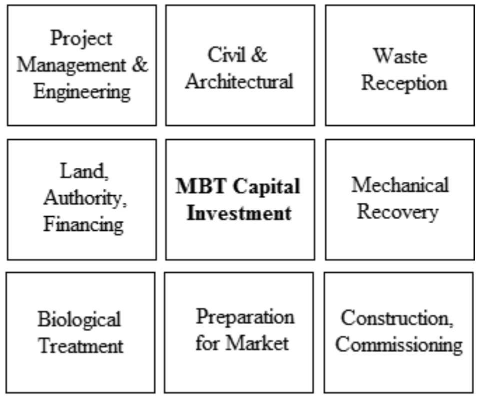

Fig. II. Capital expenditure (CAPEX) categories of a MBT facility.

A MBT facility's operation expenditure is divided into fixed and variable operating costs. Fixed costs comprise of expenses that the facility incurs irrespective of plant operational status such as manpower, financing charges, licenses while plant variable costs consists of all expenditure incurred such as utility costs and maintenance costs. Figure III divides a MBT facility's capital expenditure into 8 separate categories.

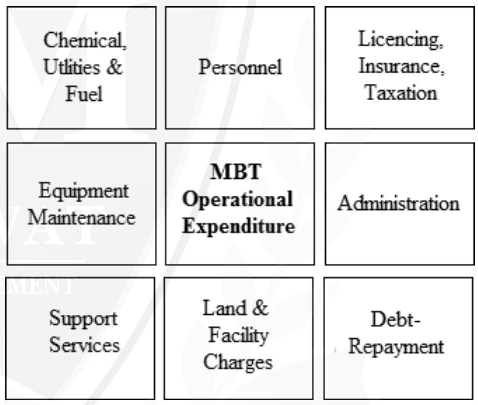

Fig. III. Operational expenditure (OPEX) categories of a MBT facility.

A MBT facility's income stream evaluation shall be based on 2 categories, i.e. (1) contracted income and (2) open-market determined income. Both income categories are performance-dependent, with open-market determined income further dependent on prevailing market rates.

D. Formulation of Waste Pricing Mechanism

The creation of the pricing mechanism to determine the suitable waste treatment fee based on pre-set internal rate-of-return (IRR) rates for the proposed mechanical biological treatment (MBT) facility to be built under the PPP model, which is derived from the general IRR formula, as shown in Equation (1).

$$NPV = \sum_{t=1}^{n} \frac{NCF_t}{(1+k)^t} - NCF_0 \qquad (1)$$

Where NCF_0 = initial cash outlay of the project
NCF_t = net cash flow at time t
n = life of the project
k = required rate of return

Equation (1) is refined to incorporate total waste receipt, facility availability rate and expected inflation rate over the life of the facility to determine the waste treatment fee per tonne processed. The IRR formula is reconstructed to present the waste treatment fee based on listed variables, aptly summarised as Equation (2).

$$\text{Waste Treatment Fee/Tonne (THB)} = \left\{ \frac{\left(\frac{\text{Waste Treatment Fee}}{\text{Facility Design Throughput}} \right) \times \text{Facility Availability}}{\text{Consumer Pricing Index}} \right\} \qquad (2)$$

Equation (2) is digitally incorporated into a computational software to allow for instantaneous data processing for the determination of possible waste treatment fees.

E. Computer Simulation Generation

The computer simulation is created on the Microsoft Excel 2013 platform. Individual spreadsheets are created within a singular workbook for purposes of data entry and processing, with respective outputs from each spreadsheet hyperlinked to the master spreadsheet for determination of the expected MSW waste treatment fee value based on case study data generation. The computer simulation is further utilised to analyze waste treatment fee structures based on potential plant efficiency and economic scenarios over the expected operating life of the facility, principally 1) plant availability, 2) changes in core inflation rate, and 3) effects on changes of biological treatment product sale pricing.

III. Data Collection

A. MSW Quantitative & Qualitative Data

A total of 28 MSW samples were collected and analyzed over a 7-day period. Table II summarises mean qualitative results for the organic components collected during the MSW sampling exercise.

TABLE II

MSW QUALITATIVE SAMPLING MEAN RESULTS

Chemical Property	Unit	Mean Results
MSW Moisture	%	70.92
pH	-	6.73
Total Solid Content	%	29.08
Carbon Content (C)	%	42.58
Nitrogen Content (N)	%	1.89
Sulphur Content (S)	Mg/kg	1,003
C/N Ratio	-	23.30
Calorific Value (Dry)	kJ/kg	15,510
Calorific Value (Wet)	kJ/kg	2,388

Table III reports the summarised mean weight and volume results (by percentage) for all samples collected during the MSW quantitative sampling exercise.

TABLE III

MSW QUANTITATIVE SAMPLING MEAN RESULTS

MSW Component	Percentage (by weight) $\overline{X}$	Percentage (by volume) $\overline{X}$
Food Waste	46.86	28.32
Yard & Garden Waste	5.53	10.80
Mixed Paper	10.75	12.06
Mixed Plastics	21.03	48.82
Wood & Fibre	0.73	
Rubber & Leather	0.55	
Ferrous Metal	0.46	
Stainless Steel	0.02	
Copper	0.03	
Aluminum	0.16	
Glass	3.03	
Ceramic, Tiles & Stones	1.76	
Foam	0.83	
Fabric & Textiles	3.96	
Hazardous Waste	0.14	
Other Waste (undefined)	4.16	

B. Selection of MBT Method

In analyzing MSW component recovery and utilisation potential, waste component is grouped by main recovery or treatment method, dependent on the intended use of each product. Table IV outlines recovery method of MSW components by recovery/ treatment method and use.

TABLE IV
MSW COMPONENT RECOVERY METHOD & USE

Waste Component/ By-Product		Recovery/ Treatment Method	Intended Use of Product
Mechanical Recovery	Ferrous Metal	Magnetic Recovery	Scrap Metal "as is" Basis
	Stainless Steel	Eddy-Current Separation	
	Copper		
	Aluminium		
	Glass	Densimetric Table, Near Infra-Red Optical Separation & Manual Picking	Disposal" as is" Basis
	Ceramics & Stones		
	Household Hazardous Waste (HHW)		Disposal in Secured Landfill
Biological Treatment	Food Waste	Size Separation, followed by Anaerobic Digestion	Biogas & Digestate for further processing
	Yard & Garden Waste		
	Recovered Leachate		
Market Prepared	Fabric, Foam & Textiles	Fine Shredding & Baling	Refused Derived Fuel (RDF) for Export
	Mixed Paper		
	Mixed Plastics		
	Wood & Fibre		
	Rubber & Leather		
	Other Wastes		
	Biogas	Biogas Scrubbing & Biogas Engine Use	Electricity
	Digestate	Dewatering & Aerobic Composting	Compost & Liquid Fertiliser

Figure IV. summarises the process flow for the mechanical recovery phase of the MBT facility.

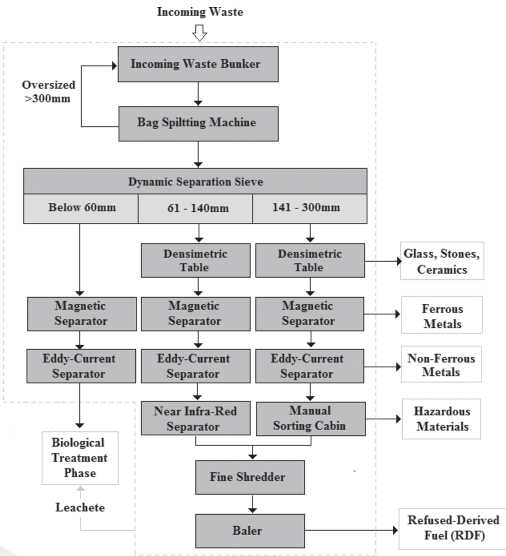

Fig. V. Process flow of case study's mechanical recovery phase.

Fig. V. summarises the process flow for the biological treatment phase of the MBT facility.

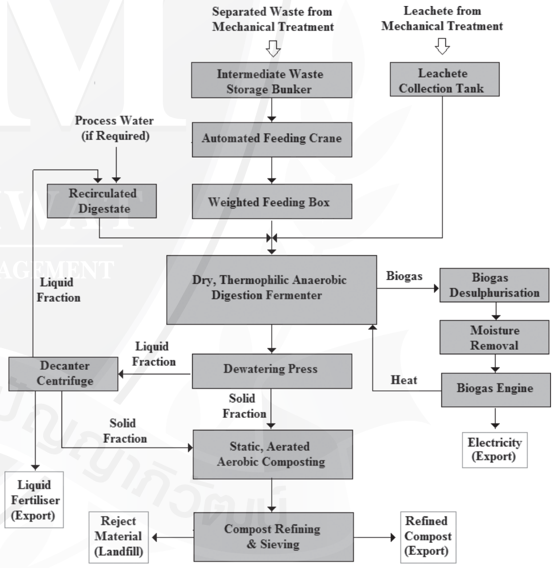

Fig. V. Process flow of case study's biological treatment phase.

C. Case Study CAPEX and OPEX Data Collection

Project capital expenditure categories are consolidated from 8 categories to determine the overall project cost. Additionally, the project's contingency budget is determined above the project base cost estimate either through range estimating, expected value or probabilistic method. The case study sets a contingency budget and construction budget of 10% and 5% respectively, above the based cost estimate. Table V summarises the case study's capital expenditure.

TABLE V

Case study capital expenditure (CAPEX)

Capital Expenditure	Cost (THB)
Land, Authority & Financing	21,670,200.00
Engineering & Project Management	80,808,569.00
Civil & Architectural Works	153,096,240.00
Waste Reception	11,690,800.00
Material Recovery	130,525,384.77
Biological Treatment	556,973,886.00
Preparation for Market	240,500,500.00
Construction & Commissioning	352,984,354.00
Project Capital Base Costs	**1,548,249,933.77**
Project Contingency	154,824,993.38
Construction Financing	77,412,496.69
Overall Project CAPEX	**1,780,487,423.84**

A MBT facility's operational income and expenditure is dependent on macro-economic changes such as core inflation and market demand. Table VI breakdowns the case study's first-year forecasted operational expenditure.

TABLE VI

Case study 1st year operational expenditure

Capital Expenditure	Cost (THB)
Personnel	30,343,575.00
Land & Facility Charges	4,413,312.00
Equipment Maintenance Expenditure	46,768,700.00
Chemicals, Utilities & Fuel	33,242,544.50
Support Services	9,766,400.00
Licensing & Insurances	3,220,000.00
Administration	3,597,150.00
Debt Repayment	211,607,752.00

A MBT facility's income encompasses tangible and measurable revenues obtained for the receipt, processing and sale of raw or processed products. Table VII highlights the case study's first-year forecasted operational revenue.

TABLE VII

Case study 1st year revenue streams

Revenue Streams	Income (THB)
Mechanically-recovered Products	14,917,663.40
Biological Treatment Products	156,985,840.00
Market-prepared Products	79,739,487.00

All data collected and project assumptions are incorporated into a dedicated computer simulation created on the Microsoft Excel for simultaneous result generation.

IV. Results

On incorporation of case study data into the computer simulation, the case study's likely waste treatment fee is computed based on Internal Rate-of-Return (IRR) scenarios of 8%, 10% and 12%. Each IRR scenario generates a complete set of project financials as the differing waste treatment fee changes the project's overall margin and cash flow over the project's intended life cycle. Figure VI presents expected waste treatment fee based on pre-determined IRR from 7.5% to 12.5%.

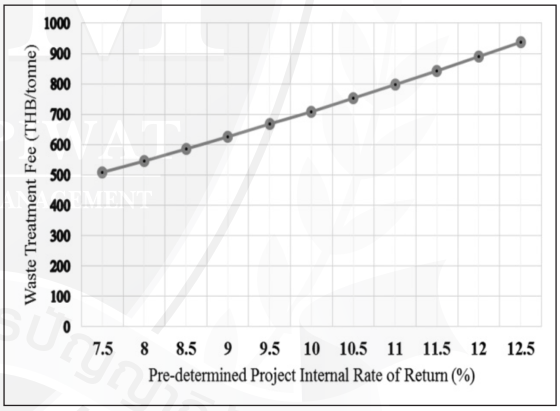

Fig. VI. Waste treatment fee based on pre-determined IRR

The simulation computed first-year waste treatment fees of THB 546.00, THB 709.00 and THB 890.00 based on pre-determined project internal rate of returns of 8.00%, 10.00% and 12.00% respectively. Results observe near-linear growth correlation between pre-determined IRR and the chargeable waste treatment fee.

The case study's computed waste treatment fee is subjected to annualised increases based on expected core inflation rate over the lifetime of the project. Based on modelling results, waste treatment fee/tonne ranges for the following IRR is observed at the following rates: 8% IRR (THB 546.00 – THB663.59), 10% (THB 709.00–THB 861.69) and 12% (THB 890.00 – THB 1081.67). Figure VII present annualised waste treatment fee pricing at pre-determined IRR over the facility's operating period.

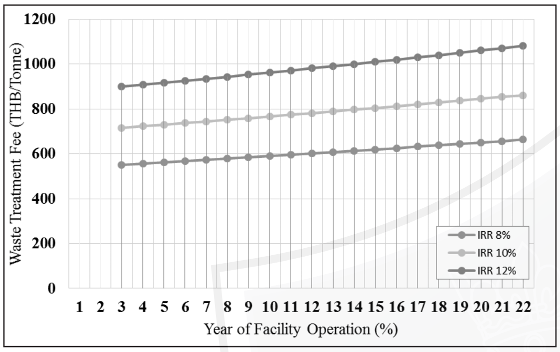

Fig. VII. Annualised treatment fee based on pre-determined IRR

The computer simulation is utilised to further analyse waste treatment fee structures based on potential plant efficiency and economic scenarios over the expected operating life of the facility.

Plant Availability

Simulation results at differing plant availability rates demonstrate that the case study's waste treatment fee rate changes by 9.30% based on annualised plant availability rate changes of 5%. Figure VIII illustrates waste treatment fee changes based on plant availability rates of 80%, 85% and 90%.

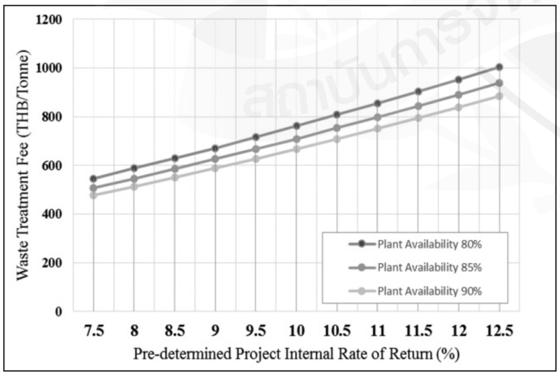

Fig. VIII. Waste treatment fee based on differing plant availability

B. Changes in Core Inflation Rates

The simulation is utilised to the case study predict waste treatment fee based on flat and increased inflation rate scenarios respectively. Table IX presents waste treatment rates based on pre-determined IRR rates between 7.50% and 12.50%, at case study pre-adjusted core inflation rates of 0% p.a., 0.98% p.a. and 1.96% p.a., respectively.

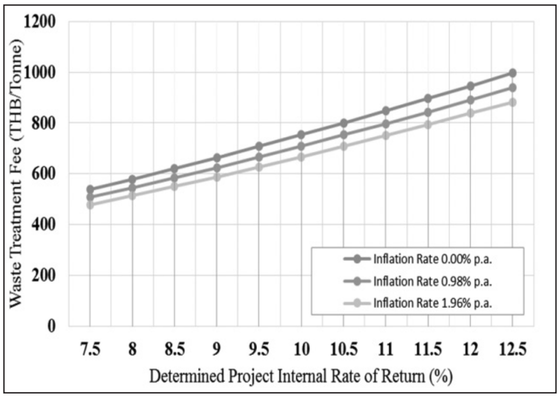

Fig. IX. Waste treatment fees by differing core inflation rates

C. Changes in Biological Product Sale Prices

The simulation is utilised to determine an appropriate waste treatment fee based on 2 differing biological sale pricing scenarios: 1) inability to monetise the sale of biologically-treated products and 2) sale price of biologically-treated products as per sale prices recorded in North Thailand (THB 3,500/tonne for finished compost and THB 1,700/m^3 for liquid fertilizer. Figure X lists waste treatment rates based on pre-determined IRR rates between 7.50% and 12.50%, at case study pre-adjusted biologically-treated product sale prices.

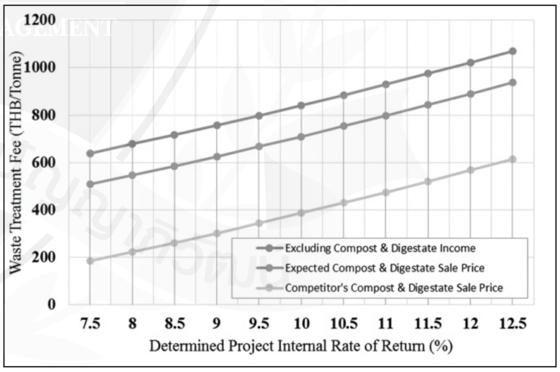

Fig. X. Waste treatment fee based on changes to sale prices of finished compost and liquid fertilizer.

V. Conclusion

The research observes that public policy and regulation play a key role in the setting of non-tariff income streams, with implementation of source separation, combination taxation, disposal taxes and disposal-refund relief contributing significantly to income potential of MBT facilities. Sampling results of Bangkok's MSW conclude that MBT processing is the best suited method for treating MSW in Bangkok, compared to direct thermal treatment.

Technical assessment indicate that dry, thermophilic anaerobic digestion is the best suited AD process for treatment of sorted organic waste due to high-levels of non-organic material contamination. While effort is taken to incorporate external market conditions, a waste treatment fee structure is highly dependent on ever changing economic conditions, on the assumption of (unlikely) fixed MSW composition over the lifetime of the facility.

The fixing of a pre-set project internal rate-of-return as the basis of determining concession rates for waste treatment facilities allow for better transparency in the awarding of projects, reducing the potential for "profiteering" and mismatched tariffs rates.

The implementation of an independently verifiable pricing mechanism as presented, increases stakeholder confidence by offering a check and balance system to confirm appropriate facility treatment fee rates set forth, while mitigating project long-term commercial risks.

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