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ECONOMIC FEASIBILITY OF WASTE-TO-ENERGY PROJECT IN THE PHILIPPINES USING REAL OPTION APPROACH

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ABSTRACT

This paper proposes an investment model to analyze the economic feasibility of WtE projects in the Philippines. Applying the real options approach (ROA) under uncertainty, we compare the option values of investing in WtE technologies over continue dumping waste into the landfill. The optimization results find that incineration is the best option followed by gasification and pyrolysis considering the energy production, investment costs, and emission rates. At the current price of electricity, it is more optimal to postpone investment in pyrolysis, otherwise, the tipping should be increased to make pyrolysis a more viable option than continue the landfill. On the other hand, it is a more optimal decision to invest immediately in either incineration or gasification as waiting to invest incurs opportunity losses from generating electricity from these technologies. The paper suggests that the government must support WtE program as it will significantly contribute in solving the problems of the environment, particularly air quality, waste management, and energy security and sustainability.

Keywords: waste to energy, investment under uncertainty, incineration, gasification, pyrolysis, real options

1. INTRODUCTION

With the growing concern for greenhouse gasses, ASEAN countries aim to harmonize the policies and regulations in renewable energy and energy efficacy. However, ASEAN has not utilized its renewable energy resources anywhere to its full potential due to significantly relying on fossil resources, constrained by strong economic growth, and socio-political and economic pressures that hinder the implementation of renewable energy policy [1]. The Philippines, in particular, is facing problems on high demand for energy and much dependence on imported fossil fuels due to recent developments and accelerated economic growth. Investments in renewable energy sources seem to be a better alternative solution that are rapidly growing in number of projects and spreading across different regions in the country [2]. At present, renewable energy (RE) accounts to 25% of the total energy generation mix and is expected to increase the capacity in the next years by investing in localized RE sources including geothermal, wind, solar, and hydropower [3].

Another promising source to supplement the country's energy needs is a waste-to-energy (WtE) facility. Currently, the country is experiencing waste management problem as it produces an average of 41,000 tons of garbage daily with more than 9670 tons per day coming from Metro Manila alone [4]. In 2001, the government enacted the RA 9003 or the "Ecological Solid Waste Management Act of the Philippines" to encourage the reduction of waste at source, recovery, recycling and reuse of wastes, creating mandatory targets through the local government units [5]. However, with the very limited number of materials recovery facilities equipped with technologies to reduce wastes like recycling and composting, most of the garbage are either disposed in dump sites or openly burned which further worsen the quality of heavy polluted air in the cities. Despite its large potential, there has never been any investment in WtE project due to lack of financing and management in the

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city level as well as the conflict with the prevailing "Clean Air Act" which prohibits incineration of municipal solid wastes. The current study aims to offer an alternative solution to address the country's problems on waste disposal and energy sustainability.

Previous literatures analyze investments in WtE technologies using traditional methods such as life cycle analysis; net present value (NPV); internal rate of return; payback period; and returns on investment [6-10]. Various studies extend these methods by combining economic analyses with social-technical and environmental aspects such as life cycle analysis, multicriteria analysis, and multistep approach [11-14]. However, these approaches do not cover some important characteristics that are crucial in making investment decisions particularly in energy investments. These include irreversibility of investment project, investment risks, uncertainty in the future cash flows, and managerial flexibility in making investment decisions. The real options approach (ROA) overcomes this limitations as it combines risks and uncertainties with flexibility in the timing of investment as an additional value to the project [2,15]. To date, there are very limited literatures applying ROA for WtE investments including anaerobic digestion (AD) of the organic fraction municipal solid waste (MSW) [16], investment valuation of Chinese Certified Emission Reduction for waste-to-power project [17]; and MSW energy recovery from incineration, gasification, and landfill biogas [18]. Our paper contributes to these literatures by applying ROA to analyze investment decisions for WtE technologies considering the uncertainty in electricity prices. Using the Philippines as a case study, our analysis focuses on developing countries that are challenged with problems on waste management and at the same time energy sustainability. Using ROA, we aim to evaluate option values and compare the economic attractiveness of either investing in WtE technologies such as pyrolysis, gasification, and incineration over continuing the landfill. We also aim to identify the optimal timing of investment and analyze benefit of postponing investments or investing immediately on these projects. We further aim to identify the electricity price and tipping fee threshold to make investments in WtE projects more viable option than landfill.

2. METHODOLOGY

2.1 WtE options

Waste to energy refers to the recovery of the energy from waste materials into usable heat, electricity, or fuel [19]. Different WtE approaches can be categorized into landfill, thermal treatment, and biological treatment as shown in Figure 1. Landfill gas recovery system (LFGRS) can be considered as a WtE technology when it generates biogas (CH_4) used for energy generation. This suits in municipalities that yield waste which is high in biodegradable content and moisture. Thermal treatment, the most commonly used large-scale WtE technology, employs the traditional incineration and more advanced pyrolysis and gasification [20]. While pyrolysis and gasification involve manual sorting and indirect combustion of MSW to mainly produce syngas, incineration involves a direct combustion of unprepared

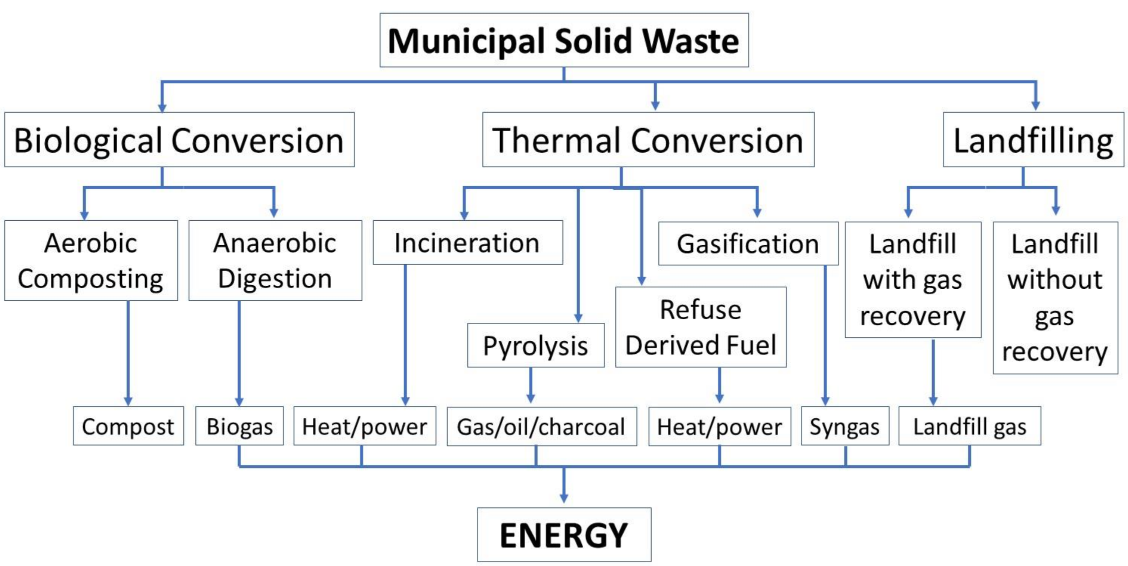

Figure 1. Municipal solid waste treatment techniques and their products [20].

MSW that yields enough energy to power a steam turbine. Biological treatment on the other hand involves aerobic composting and anaerobic digestions which produces fertilizer or biogas [19]. Among these treatment technologies, our study focus on thermal treatments in line with the government's WtE projects under evaluation.

2.2 Real options model

We consider an investor who is given a certain decision-making period T_L to either invest in WtE project k or continue dumping all MSW in the landfill L. Currently, the available WtE options in the country include $k=1$ incineration; $k=2$ gasification; and $k=3$ pyrolysis. The net present value NPV_{k} of each investment is calculated using Equation 1

$$NPV_k = \frac{\sum B_k - \sum C_k}{(1+\delta)^t} - I_k \qquad (1)$$

where I_{k} is the investment cost for technology k at δ discount rate; B_1 is the revenue for incineration; B_2 for gasification; B_3 for pyrolysis; C_1 is the costs for incineration; C_2 for gasification; C_3 for pyrolysis. The revenues include the tipping fee and the amount of electricity generated from each technology times the generate rate. The costs include all operations, maintenance, insurance, and employees salary.

Following previous literatures [21-23], we assume that the price of electricity P_e is stochastic and follow Geometric Brownian motion (GBM) with a drift as shown in Equation 2

$$dP_e = \mu P_e dt + \sigma P_e dz \qquad (2)$$

where μ is the growth rate of electricity price, σ is the volatility, and dz is a Wiener process equal to $\varepsilon\sqrt{dt}$ such that $\varepsilon \sim N(0,1)$ is a normal distribution with zero mean and one standard deviation.

We estimate the path of electricity prices using Monte Carlo simulations as shown in Equation 3. Let $0 \le t_1 < t_2 < \ldots < t_n$ be the points in time and $\Delta t = t_1 - t_{i-1}$, we generate a standard normally distributed random numbers $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n$ and estimate $P_{e,t}$ with the current electricity price as $P_{e,0}$.

$$P_{e,t} = P_{e,t-1}\, exp\left[\left(\mu - \frac{1}{2}\sigma^2\right)\Delta t + \sigma\sqrt{\Delta t}\varepsilon_t\right] \qquad (3)$$

Applying stochastic prices of electricity, we estimate the expected net present value $\mathbb{E}[NPV_k]$ of each WtE options by calculating the $NPV_{k,j}$ in a large number of J times and taking its average from initial prices of electricity as shown in Equation 4.

$$\mathbb{E}\left[NPV_{k,j}\middle|P_{e,0}\right] = \approx \frac{1}{J}\sum_{1}^{J} NPV_{k,j} \approx \mathbb{E}\left[NPV_k\middle|P_{e,0}\right] \qquad (4)$$

Using dynamic optimization, the investors problem is to find the optimal timing of investment τ_k by maximizing the value of k investment for each decision-making period as shown in Equation 5.

$$max\left\{\begin{matrix} \sum_0^{\tau_k} \rho^t \pi_{L,t} + \\ \left(\left(\sum_{\tau_k}^{T_L} \rho^t \pi_{L,t}\,(\mathbb{I}_k - 1), \mathbb{E}[NPV_k]\,(\mathbb{I}_k)\right)\right)\end{matrix}\right\} \qquad (5)$$

where $\rho^t = \frac{1}{(1+\delta)^t}$; $\mathbb{I}_k$ is an indicator equal to 1 if investment is made, otherwise equal to zero; and $\pi_{L,t}$ is the annual cash flow for the landfill equal to the revenue from tipping fee minus the operations and managements costs.

The problem is solved by calculating the option value $V_{k,t}$ at each decision-making period by either investing in k or continue dumping all waste in the landfill as shown in Equation 6.

$$V_{k,t} = max\{\pi_{L,t}, \mathbb{E}[NPV_k]\middle|P_{e,t}\} \qquad (6)$$

The optimal timing of investment for each type of project is characterized by the maximum price of electricity where the option value of each project at initial period is equal to the option value at the terminal decision-making period as shown in Equation 7.

$$P_e^{k^*} = max\{P_{e,0}\middle|V_{k,0}(P_{e,0}) = V_{k,T_k}(P_{e,0})\} \qquad (7)$$

Further, we estimate the value of waiting to invest in each WtE technology $V_{wait,k}$ as the difference between the option value at terminal period V_{k,T_k} minus the option value at the initial decision-making period $V_{k,0}$ at the current price of electricity P_e^{cur} as described in Equation 8.

$$V_{wait,k} = V_{k,T_k}(P_e^{cur}) - V_{k,0}(P_e^{cur}) \qquad (8)$$

2.3 Parameter estimation

To estimate the parameters for the optimization problem, we gather the data from Philippine's Department of Energy (DOE), National Solid Waste Management Commission (NSWMC) of the Department of Environment and Natural Resources (DENR), and Clean Technology Solutions. For standard comparison of the WtE technologies, we set the plant capacity to 100 tons/day and assume that the plant generates electricity a year after the investment period. NPV calculations are done in a 20 year period of electricity generation for all technologies at 10% discount rate. We use a 10-year time series data of electricity prices to approximate the future stochastic prices of electricity. Using ADF unit root test, we confirm that electricity prices follow GBM with $\mu = 0.028651$ and $\sigma = 0.12192$. We set the initial prices of electricity from PHP1/kWh to PHP20/kWh at PHP0.25/kWh step. For each initial prices, we calculate the expected NPV of each type of WtE technology. On the dynamic optimization, we maximize the value of either investing in WtE or continue landfill from initial to terminal decision-making period $T_L = 25$ years. For sensitivity analysis, we compare the option values for each WtE at various levels of tipping fee from the current US$15/ton to US$20/ton, US$10/ton, US$5/ton, and zero tipping fee.

3. OPTIMIZATION RESULTS

3.1 Baseline scenario

The result of dynamic optimization is shown in Figure 2. Each point on the curve represents the option values which are described in Equation 6 at every initial prices of electricity. The optimal timing of investment is describe as the maximum price of electricity where bold and fine curves overlap. The results show that optimal timing of investment for pyrolysis is $P_e^{P^*} = PHP6.00/kWh$, $P_e^{G^*} = PHP3.25/kWh$ for gasification, and $P_e^{I^*} = PHP1.50/kWh$ for incineration. This indicates that among the alternatives, investment in incineration is the best option, followed by gasification and pyrolysis. This is further supported by higher option value curves for incineration which indicate higher profitability in this technology. This result verifies previous studies showing incineration to be more attractive than the competing alternatives due to its higher power production efficiency, lower investment costs, and lower emission rates [18, 19].

In Figure 2, the option value curves at the initial period of investment are higher than the terminal period of investment for all types of technology. These implies that investing immediately is a better option than postponing investments in WtE. At the current electricity generation price $P_e^{cur} = PHP5.5508/kWh$, the value of waiting for investment in incineration is -PHP8541million; -PHP5557million for gasification; and zero for pyrolysis. This indicates that waiting to invest in incineration and gasification incurs opportunity losses

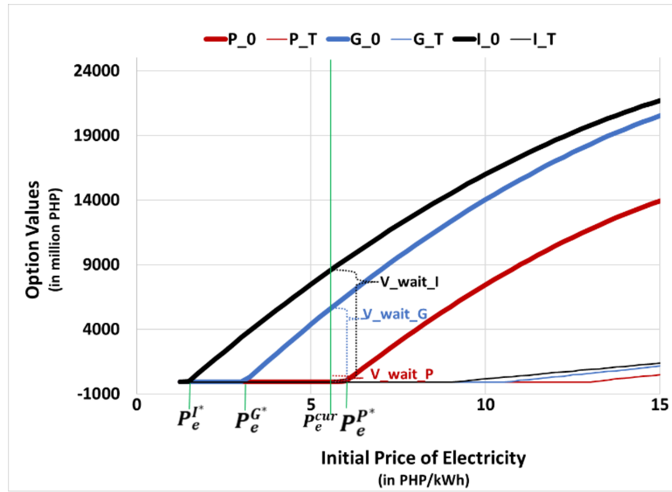

Figure 2. Option value of various WtE investments at different initial prices of electricity

Note: P_0 indicates the option value curve for pyrolysis at initial decision-making period; P_T for terminal period; G_0 for gasification at initial decision-making period; G_T for terminal period; I_0 for incineration at initial decision-making period; I_T for terminal period. V_wait_I indicates the value of waiting to invest in incineration; V_wait_G for gasification; and V_wait_P for pyrolysis. The current price of electricity P_e^{cur} is PHP 5.5508/kWh (May 2018). The optimal timing of investments are $P_e^{I^*}$ for incineration; $P_e^{G^*}$ for gasification; and $P_e^{P^*}$ for pyrolysis.

from selling the electricity generated from these alternatives at the current investment environment. On the other hand, investment in pyrolysis is only profitable at electricity prices higher than the optimal timing $P_e^{P^*} = PHP6.00/kWh$. Further, investments done at electricity prices lower than the optimal timing of investments $P_e^{G^*}$, $P_e^{I^*}$ and $P_e^{P^*}$, may result to negative option values which implies negative profits. These results highlight the advantage of using ROA over traditional project valuation methods as it combines uncertainty and risk with flexibility while considering the volatility in investment as a potential positive factor which gives additional value to the project [2,15].

3.2 Tipping fee scenario

In this scenario, we describe how sensitivity in tipping fee affects investment decisions in WtE. At present, the average tipping fee in the Philippines is US$ 15/ton of waste collected from the households. We also identify the critical value of tipping fee that makes WtE technologies more viable option than landfill. Figure 3 describes the dynamics of optimal prices of electricity at

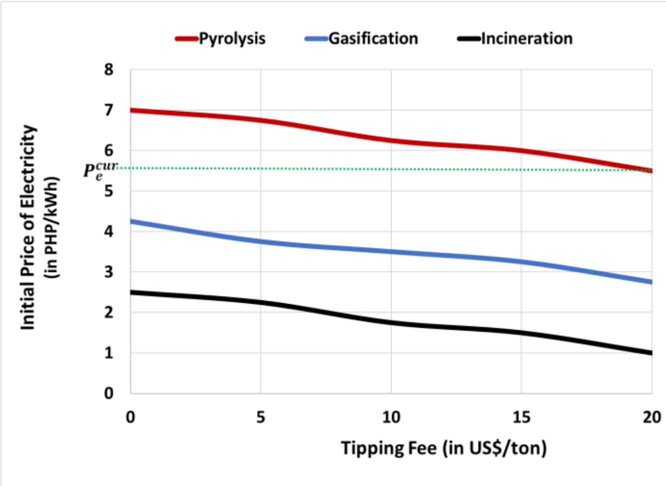

Figure 3. Optimal prices of electricity for investing in Wte technologies at different values of tipping fee

Note: The current tipping fee is $15/ton (1US$=PHP45.85).

different values of tipping fee. The result shows the inverse relationship between the optimal prices of electricity for making WtE investments and the value of tipping fee. This indicates that WtE becomes more attractive than landfill as the increase in tipping fee incurs additional revenue for these types investments. The result confirming incineration to be the most profitable alternative is robust at various levels of tipping fee. Further, the critical value of tipping fee for pyrolysis is at US$18.5/ton. This implies that in order to make pyrolysis more attractive option than landfill, the tipping fee must be increased to this critical value from its current value. On the other hand, we do not estimate the critical value for incineration and gasification as these alternatives are already viable options than landfill as explained in the previous subsection.

3.3 Discussion

Developing countries, like the Philippines, have limited experience on WtE plants. However, the rise on waste quantities in traditional landfill, growing health and environmental problems, and energy demands urge the government to respond and adapt to alternatives that these technology offers. In this study, we analyze three WtE technologies: incineration, gasification, and pyrolysis. Among these technologies, incineration yields the highest amount of electricity with the highest capacity to lessen pile of wastes in landfills through direct combustion. However, Philippine Clean Air Act of 1999 prohibits burning of garbage therefore tending this option useless unless the government amends the law. In terms of operations and maintenance cost, gasification and pyrolysis are more expensive than incineration. With the high investment costs, private investors may play an important role for this project. However, in most developing countries, private investors are still reluctant to invest due to the associated financial risks. This can be addressed by providing guaranteed legal security, transparency, and clear vision for a sustainable waste management services [24].

In this study, we focus our real options analysis on the financial feasibility of WtE alternatives. In real project decision making, there are other several factors considered in order to approve a project that involves environmental and health risks. We recommend to extend this research by including environmental assessment; health risk analysis; and economic impacts on income, employment, and local electricity market. ROA may also incorporate technical and nontechnical uncertainties in government policy, social acceptance, and waste management laws. Further studies may also consider other WtE options including thermal depolymerization, plasma gasification, and non-thermal technologies such as anaerobic digestion, fermentation, and mechanical biological treatment. Despite the limitations, we believe that this research is a good benchmark for further analysis to address the country's energy and waste management issues and to significantly contribute in its action towards achieving the sustainable development goals.

4. CONCLUSION

In this study, we highlight ROA to describe the flexibility in making WtE investment decisions under uncertainties. Our results conclude that WtE technologies are better options than continue dumping wastes on the landfill. Among the alternatives investigated, incineration appears to be the most profitable option, followed by gasification and pyrolysis. Considering the current price of electricity, it is more optimal to wait to invest in pyrolysis. Otherwise, the tipping should be increased to make pyrolysis a more viable option than continue the landfill. On the other hand, it is a more optimal decision to invest immediately in either incineration or gasification as waiting to invest incurs opportunity losses from generating electricity from these technologies. The paper suggests that the government must support WtE program as it will significantly contribute in solving the problems of the environment, particularly air quality, waste management, and energy security and sustainability.

REFERENCE

[1] Mamat R, Sani MSM, Sudhakar K. Renewable energy in Southeast Asia: Policies and recommendations. Science of The Total Environment 2019; 670:1095-1102.

[2] Agaton CB. A Real Options Approach to Renewable and Nuclear Energy Investments in the Philippines. Vol. 71. Logos Verlag Berlin GmbH; 2019.

[3] Agaton C. To Import Coal or Invest in Renewables? A Real Options Approach to Energy Investments in the Philippines. In: Sayigh A, editor Transition Towards 100% Renewable Energy. Cham: Springer; 2018, p.1-10.

[4] Metro Manila Development Authority. Solid Waste Management in Metro Manila 2018.

[5] Paul JG, Arce-Jaque J, Ravena N, Villamor SP. Integration of the informal sector into municipal solid waste management in the Philippines–What does it need?. Waste Management 2012; 32(11):2018-2028.

[6] Abdallah M, Shanableh A, Shabib A, Adghim M. Financial feasibility of waste to energy strategies in the United Arab Emirates. Waste Management 2018; 82:207-219.

[7] Alzate-Arias S, Jaramillo-Duque Á, Villada F, Restrepo-Cuestas B. Assessment of government incentives for Energy from Waste in Colombia. Sustainability 2018; 10(4):1294.

[8] dos Santos RE, dos Santos IF, Barros RM, Bernal AP, Tiago Filho GL, da Silva FD. Generating electrical energy through urban solid waste in Brazil: An economic and energy comparative analysis. J of envi management 2019 ; 231:198-206.

[9] Hadidi LA, Omer MM. A financial feasibility model of gasification and anaerobic digestion waste-to-energy (WTE) plants in Saudi Arabia. Waste management 2017; 59:90-101.

[10] Ogunjuyigbe ASO, Ayodele TR, Alao MA. Electricity generation from municipal solid waste in some selected cities of Nigeria: An assessment of feasibility, potential and technologies. Ren & Sus En Reviews 2017; 80:149-162.

[11] Ayodele, T. R., Ogunjuyigbe, A. S. O., & Alao, M. A. Life cycle assessment of waste-to-energy (WtE) technologies for electricity generation using municipal solid waste in Nigeria. Ap energy 2017; 201:200-218.

[12] Fernández-Gonzalez JM, Grindlay AL, Serrano-Bernardo F, Rodríguez-Rojas MI, Zamorano M. Economic and environmental review of WtE systems for municipal solid waste management in medium and small municipalities. Waste Management 2017; 67:360-74.

[13] Abdallah M, Shanableh A, Arab M, Shabib A, Adghim M, El-Sherbiny R. Waste to energy potential in middle income countries of MENA region based on multi-scenario analysis for Kafr El-Sheikh Governorate, Egypt. J of Envi Management 2019; 232:58-65.

[14] Panepinto D, Zanetti MC. Municipal solid waste incineration plant: A multi-step approach to the evaluation of an energy-recovery configuration. Waste management 2018; 73:332-341.

[15] Agaton CB. Real Options Analysis of Renewable Energy Investment Scenarios in the Philippines. Ren En & Sus Dev 2017; 3(3):284-292.

[16] Ranieri, L., Mossa, G., Pellegrino, R., & Digiesi, S. Energy recovery from the organic fraction of Municipal Solid Waste: A real options-based facility assessment. Sustainability 2018; 10(2):368.

[17] Chunyan D, Yixian W, Yanling Z. "Research on the Investment Valuation of the CCER Project for Waste-to-Power Based on the Real Option Model," Journal of Economics, Business and Management 2018; 6(3):91-96.

[18] Tolis A, Rentizelas A, Aravossis K, Tatsiopoulos I. Electricity and combined heat and power from municipal solid waste; theoretically optimal investment decision time and emissions trading implications. Waste management & research 2010; 28(11):985-995.

[19] Tan ST, Ho WS, Hashim H, Lee CT, Tai MR, Ho CS. Energy, economic and environmental (3E) analysis of waste-to-energy (WtE) strategies for municipal solid waste (MSW) management in Malaysia. En Con and Management 2015; 102:111-20.

[20] Kumar A, Samadder SR. A review on technological options of waste to energy for effective management of municipal solid waste. Waste Management 2017; 69:407-422.

[21] Hou Y, Liu CC, Salazar H. Electricity Prices as a Stochastic Process. In M. E. El‐Hawary (Ed.). Advances in Electric Power and Energy Systems: Load and Price Forecasting; 2017,p.89-152.

[22] Zambujal-Oliveira J. Investments in combined cycle natural gas-fired systems: A real options analysis. Int J of Elec Pow & En Systems 2013; 49:1-7.

[23] Maeda M, Watts D. The unnoticed impact of long-term cost information on wind farms' economic value in the USA – A real option analysis. Ap Energy 2019; 241: 540-547.

[24] Mutz D, Hengevoss D, Hugi C, Gross T. Waste-to-Energy Options in Municipal Solid Waste Management A Guide for Decision Makers in Developing and Emerging Countries. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 2017.

