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THE RENEWABLE ENERGY SOURCES FOR MUNICIPAL WASTEWATER PROCESSES IN THAILAND: A CASE STUDY OF THE NONTHABURI WASTEWATER TREATMENT PLANT

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Abstract

There are 101 municipal wastewater treatment plants in Thailand supplied with electricity and cannot collect wastewater treatment fees. Alternative sources of energy for municipal wastewater treatment would reduce the electricity costs and future fossil energy uses. The Nonthaburi wastewater treatment plant (WWTP) is located in the Northwest of Bangkok and selected due to its available data. The solar energy source is applied to the Nonthaburi WWTP due to the light intensity and the area to install. By comparing to the wind and the biogas sources, the wind speed and the sludge production are not sufficient, respectively. Besides the estimated installation cost of the solar-cell panels among three companies, the NPV of 25 years and the IRR of three percent rate, the area required for installation is an affecting factor for the plant consideration.

Keywords:

Biogas;
Net present value;
Internal rate of return;
Solar panel;
Wind energy.

1 Introduction

Environmental issues have become a matter of serious concern in global politics [1-2]. The main energy used in wastewater treatment systems in Thailand is electricity. As a result of the increase in water usage in municipal areas, the cost of electricity in municipal wastewater treatment plants has increased. At present, some areas have issued policies to collect the wastewater treatment fee which has not yet come to a concrete conclusion due to many organizations and government agencies involved. Therefore, reducing electricity costs is an option for budget management. The use of renewable energy in wastewater treatment plants is an alternative to current and future scenarios. The purpose of this work is to investigate the electricity cost associated with municipal wastewater treatment systems and the potential renewable energy sources for use in the systems.

Some local government administrations in Thailand may not collect data on their work, otherwise, the request for the information is prolonged, or, do not get the information that should be. A case study assists to analyze forward projections. One municipal administrative of wastewater treatment plant located in Nonthaburi province, Northwest of Bangkok, was contacted and to provide the electrical cost for the whole administration. The information was not separated as the department related to. Based on the data of the machines operated of the type of wastewater treatment process and the influent flow rate, it requires cooperation from the operational staff and the chief.

2 Methods

Secondary data related to municipal wastewater treatment systems in Thailand and the possible renewable energy sources are collected, analyzed and applied to a case study. The Nonthaburi wastewater treatment plant, located on the northwest of Bangkok, was selected due to its data available.

2.1 Case study

Nonthaburi province is located in the Northwest of Bangkok City. The municipal wastewater treatment plant with a capacity of 38,500 m^3/d is served for a population of 240,000 people. Raw municipal wastewater undergoes preliminary, primary, and secondary treatment to yield treated effluent and dewatered sludge. The typical municipal wastewater treatment process is an extended aeration activated sludge which includes screening, aerated grit removal, oxidation, and sedimentation.

The equipment that requires electricity in the operating system is the pumps and aerators in the pumping station and aeration tanks. The electrical power was supplied at 484 kWh or cost of 954 Baht/h (USD 29/h) in the year 2016 [3]. The wastewater flow to the treatment plant was 20,832 m^3/d in the year 2017, while the electric charge was 14 Baht/m^3 (USD 0.42 /m^3) of treated effluent.

2.2 Renewable energy sources

2.2.1 Solar energy

The important parameters of solar cells are the intensity of light [4] and the temperature of the current. When the temperature rises to an average of every 1 ºC increasing, causing the voltage to decrease by 0.5 % [5]. The daily average solar radiation intensity of Thailand is equal to 18 MJ/m^2·d and an average of 6 hours a day with sunlight in 2017 [6]. The minimum and maximum raining days from 2003 to 2015 were 95 and 138 days a year in Nonthaburi province.

2.2.2 Wind energy

Wind energy from the turbine can be used to generate the amount of electricity that depends on 3 factors: the speed of the wind, the length of the propeller, and the location of the wind turbine installation. In Thailand, the wind is mostly at speeds of 1.1 - 1.4 m/s. In accordance with the criteria for installing wind turbines, the annual average wind power should be at class 3 that is 6.4 - 7.0 m/s or 300 - 400 kW/m^2 [7].

The problem of installation at the Nonthaburi WWTP is that the wind speed in the area is low and the no sea-area to increase the wind speed efficiency. Wind currents in the area are not continuous and the landscape is not flat, rather open with barriers to the wind. For these reasons, therefore, wind energy is not suitable for application at the Nonthaburi WWTP.

2.2.3 Biomass energy

Biomass energy is caused by the decomposition of organic matter in anaerobic conditions, a process of transforming organic matter into biogas. The Nonthaburi WWTP produces 162 m^3/d of sludge. In fact, the amount of biogas produced from 1 m^3 of sludge is 10.31 m^3 and 1 m^3 of biogas can be converted to electricity 1.20 kWh. Within a day, the sludge is converted into electricity as 2004 kWh.

2.3 Calculations of the expense

2.3.1 The electricity charge

The Provincial Electricity Authority of Thailand has divided the electricity tariff into 7 categories, namely:

1) Residential house,
2) Small business,
3) Medium business,
4) Large business,
5) Specific business,

6) Government sector and non-profit organizations,
7) Pumping water for agriculture.

The electricity tariff of Nonthaburi WWTP is classified in category 6.

The normal rate of electricity category 6 is the voltage from 69 kW and above. The electricity charge is 1.9712 Baht per unit. The service charge is 228.17 Baht per month [8].

2.3.2 Solar cell services

The service charge for cleaning and inspecting solar cells is calculated annually at the price of 350,000 Baht per MW by checking at the site every 3 months and cleaning 4 times per year. There is a service fee paid once, based on the power, such as power less than 1 MW, priced at 50,000 Baht. There is a travel fee of 5,000 Baht per time in a given distance [9].

The management of used solar panels in the country is the separation of waste and then shredded into small pieces before entering the process of stabilizing then transferring to secured landfills.

A company in the world market has a market share in the top 3 in the world. The solar cells of this company have been in development for more than 30 years ensuring that the efficiency of power generation is as long as the manufacturer guarantees at 25 years. The efficiency will be reduced by an average of 0.8 percent per year, which after 25 years, solar panels will still be able to operate but the efficiency will be about 80 percent.

2.3.3 Solar panel installation companies

Requirements for choosing solar panel installation are companies that have solar panels installed for government agencies and are firm companies then choose to compare three companies, so-called, Company A, Company B, and Company C [9-11].

Company A is a member of the Thai Solar Cell Industry Association and is a partner with National Science and Technology Development Agency (NSTDA) in conducting joint research on solar roof installations for household and industrial businesses. Company B is a solar panel installation company for saving electricity bills in homes, offices, and industries. The quality is a premium solar panel that is inexpensive, can be used for at least 25 years. At last, company C is a company selling all kinds of products of all sizes at retail and wholesale prices. That is cheap and of good quality. Products selected and related to solar panels are presented in Table 1.

Table 1: Solar cell panels detailed of the companies A, B, and C based on the year 2017.

Item	Products and services	A	B	C
1	Maximum power [kW]	14.4	20	10
2	Numbers of solar cell	-	58	40
3	Payback time [yr]	7	-	-
4	Area installation [m^2]	77	120	-
5	Inverter type	-	-	Grid schneider conext RL 5000E
6	Price per unit [kBaht]	849	950	320

3 Results and discussions

3.1 Processes and the capacities

There are 101 municipal wastewater treatment plants in Thailand in 2016. The process types are grouping into 5 major categories: Aerated Lagoons (AL), Activated Sludge (AS), Rotating Biological Contactors (RBC), Stabilization Ponds (SP), and Artificial Ponds (AP). The highest capacity is the activated sludge process as shown in Table 2.

Table 2: The processes and capacities of municipal WWTP in Thailand by the year 2016.

Types of process	Numbers of plant	Capacity [m^3/d]	Percentage of capacity [%]
Aerated lagoons (AL)	18	393,400	11.95
Activated sludge (AS)	37	2,195,400	66.70
Rotating biological contactors (RBC)	1	8,000	0.25
Stabilization ponds (SP)	41	436,775	13.27
Artificial ponds (AP)	4	257,900	7.83
Total	101	3,291,475	100.00

The cost of wastewater treatment was estimated at 65 Baht/m^3 based on the available data of 59 wastewater treatment plants by the Water Quality Management Bureau, Pollution Control Department in 2016.

3.2 Nonthaburi WWTP

The average light intensity is 16.9 MJ/m^2·d which is sufficient for the solar panel installation criteria as specified by the Ministry of Energy. The average wind speed is 1.1 m/s which is lower than the wind speed standard 4 m/s for installing wind turbines. Although other research suggests that wind power is the most sustainable renewable energy [12]. From our data, the 162 m^3/d sludge production capacity is not worth the construction of biomass systems in the Nonthaburi WWTP area. Biomass yields around the year 2015 have been estimated to increase mostly from traditional agriculture crops and harvest residues [13].

3.3 Power electricity requirement

At Nonthaburi WWTP, six mechanical devices need electrical supplying as shown in Table 3.

Table 3: Electricity need for the mechanical devices of the Nonthaburi WWTP.

Item	Mechanical device	Numbers of the device	Numbers of the spare	Input electrical power [kWh]	Working hours a day [kW]	Usage of device [%]
1	Pump	3	1	75	1,125	23.8
2	Pump RV	1	1	30	150	3.2
3	Automatic sweeper	1	0	72	360	7.6
4	Single turbo blower	2	1	298	2,980	63.0
5	Sludge sweeper	4	4	4.8	96	2.0
6	Sludge pump	1	0	4	20	0.4
	Total	-	-	-	4,731	100

The guidance of Alternative Energy Development Plan (AEDP) in 2015 [14] for renewable energy compensation is 30 % reduction of the total electricity usage. The average number of hours of sunlight is 6 hours a day which is the number of hours for power produced by the solar panel. Therefore, the Nonthaburi WWTP power required to compensate is 237 kWh that is the actual power required to reach 30 % of the renewable energy from sunlight. Based on the calculation of actual power produced by a solar panel Eq. (1), resulting the Nonthaburi WWTP of 335 kWh required from the solar panel power produced.

$$APP = PSP \times f_t \times f_{dir} \times f_{mis} \times f_{inv}\,, \tag{1}$$

where APP is the actual power produced; PSP is the solar panel power produced; f_t is the temperature effect 0.89; f_{dir} is the dirty and dust effect 0.93; f_{mis} is the loss of panel effect 0.95, and f_{inv} is the invert power effect 0.90.

Table 4: Comparisons on the installation cost of the three companies in a period of 25 years.

No.	Item	Company A	Company B	Company C
1	Solar panel power produced [kWh]	14.4	20	10
2	Cost per panel [kBaht]	849	950	320
3	Numbers of solar panel	24	17	34
4	Area required [m^2]	1,848	2,040	2,244
5	Solar panel insurance [yr]	25	25	25
6	Power inverter insurance [yr]	10	5	5
7	Installation cost [MBaht]	20.38	16.15	10.88
8	Electricity production value [MBaht]	12.59	13.76	13.43

For the maintenance of the solar panel after installation, there is one company that accepts annual contract operation at 355,000 Baht. Based on the efficiency of electricity production by the solar panel is reduced by 0.8 % every year for 25 years, the solar panel installation value of the A, B and C companies will reduce at the electricity production values to 12.59, 13.76 and 13.43 MBaht, respectively, while the costs of installation are respectively 20.38, 16.15 and 10.88 MBaht.

Beside the installation cost of the solar panels among 3 companies, the Net Present Value (NPV) of the 25-year period and the Interest Rate of Return (IRR) of 3 percent rate [15], indicated that Company C would be an appropriate investment of the solar energy at Nonthaburi WWTP with the roof area of 2,244 m^2. The results of NPV and IRR are summarized in Table 5.

Table 5: The NPV of 25-year period and the IRR of 3 % among the A, B, and C companies.

Company	NPV [MBaht]	IRR [%]	Area of installation [m^2]	Area usage [%]
A	-6.72	-22	1,848	4.07
B	-2.09	-6	2,040	4.62
C	2.54	17	2,244	5.07

4 Conclusion

By comparison, the costs of solar panel installation and maintenance from Company C are recommended to the Nonthaburi WWTP. Another two factors are the climate conditions for solar energy and the area required for the solar panel installation. These factors are the light intensity 16.9 $MJ/m^2 \cdot d$, the number of hours of sun exposure 6 hours a day, including the amount of space area required (5.07 % of the total area) to install the solar panels causing Nonthaburi WWTP to be a model for using solar cells to replace electricity in the future. The installation of solar panels at Nonthaburi WWTP would be a model to estimate the same type of municipal WWTP in Thailand for solar renewable energy of 30 %.

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