PROCESS IMPROVEMENT AND ENERGY SAVING MEASURES FOR SEWAGE TREATMENT PLANT

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ABSTRACT

Energy in sewage treatment plant (STP) show the differential energy consumption on various stages which it depends on the indicator of the findings. To do comparison and benchmarking, the suitable key energy consumption indicator need to identify, and the suitable method need to formulate in performing the energy. This study is to perform energy saving measures (ESM) and process improvement for the STP. The study started with planning to select the STP and study on the potential of method to use. Sites visit then conducted to make an overall overview of STP and the related data was collected to do analysis. The propose ESM and process improvement analyzed in term of results feasibility, findings, and economic analysis. Introducing the Solar PV systems by do comparison type of panel and area available will determine the potential of savings. Retrofitting the lighting for existing 36W fluorescent to LED T8 14W and for 300W spotlight to 150W LED spotlight also help the STP to reduce the energy consumption. Retrofitting the Sequencing Batch Reactor (SBR) to produce biogas and the development of Combine Heat and Power (CHP) plant to generate electricity will reduce the demand of electricity from the grid. The waste heat produced later can be used for sludge dewatering process. Sludge utilization will help the STP to generate yearly income rather than allocate budget for the sludge removal from the STP. The overall result which is categorized according to the options will the analyzed to perform the best selected option. The best option is to utilize all the available potential area of Solar PV installation along with another ESM and utilization to obtain the best result. The combination of proposed improvement being analyzed according to the selected option, economic feasibility, energy savings, CO_2 reduction and simple payback period with expected reducing the energy consumption and cost at the STP. As conclusion, the implementation of all the propose ESM and utilization will lead the savings in many aspects of area to the STP.

ABSTRAK

Tenaga di loji rawatan kumbahan menunjukkan perbezaan pada pelbagai peringkat yang mana ianya bergantung kepada penunjuk aras penggunaan tenaga. Untuk membuat perbandingan dan penanda aras, penunjuk aras penggunaan tenaga yang utama hendaklah dikenalpasti dan kaedah yang sesuai hendaklah digunakan untuk merumuskan pengunaan keseluruhan tenaga. Kajian ini adalah untuk mencadangkan langkah penjimatan tenaga (ESM) dan penambahbaikan kepada proses pada loji kumbahan ini. Kajian bermula dengan merancang untuk memilih loji kumbahan dan kaedah yang sesuai untuk digunakan. Lawatan tapak telah dijalankan untuk mendapatkan gambaran keseluruhan berkaitan loji kumbahan dan pengambilan data yang diperlukan juga direkodkan untuk analisa lanjut. Cadangan langkah penjimatan dan penambahbaikan proses dianalisa meliputi skop kebolehlaksanaan, jumpaan analisis dan juga analisa dari sudut ekonomi. Sistem solar PV dicadangkan dengan membuat perbanding pada jenis panel yang digunakan dan juga mengenalpasti kawasan yang berpotensi untuk dibangunan sistem ini. Pengubahsuaian ke atas sistem lampu sediaada dengan menukar lampu jenis 36W pendarflor kepada jenis LED T8 14W dan lampu tumpu sediaada 300W kepada jenis LED 150W dapat membantu kepada pengurangan tenaga di loji ini. Pengubahsuaian ke atas tangki S*equencing Batch Reactor* (SBR) adalah untuk penghasilan biogas dan pembangunan loji *Combine Heat and Power* (CHP) adalah untuk penjanaan elektrik dan dapat mengurangkan kebergantungan kepada grid. Haba yang dijana boleh digunakan untuk proses penyahairan enapcemar. Penggunaan optimum enapcemar dapat membantu loji untuk mengurangkan kos pengurusan sediaada dengan menjual enapcemar yang terhasil untuk proses lain dan dapat menjana pendapatan kepada loji. Keputusan kajian secara keseluruhan dibahagikan mengikut pilihan dan analisa dijalankan untuk menentukan pilihan terbaik yang mana adalah dengan menggabungkan semua langkah penjimatan yang dicadangkan. Kombinasi pilihan dianalisa mengikut kategori pilihan, kebolehlaksanaan, penjimatan tenaga, pengurangan CO_2 dan tempoh bayaran balik dengan jangkaan pengurangan penggunaan tenaga dan penjimatan kos kepada loji. Kesimpulannya perlaksanaan semua langkah penjimatan akan menghasilkan penjimatan dari sudut pelbagai aspek pada loji rawatan kumbahan ini.

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STP	-	Sewage Treatment Plant
GHG	-	Greenhouse Gas
AD	-	Anaerobic Digestion
SEDA	-	Sustainable Energy Development Authority
RE	-	Renewable Energy
IM	-	Improvement Measures
HVAC	-	Heating Ventilation and Air Conditioning
ACMV	-	Air-conditioning and Mechanical Ventilation
LCCA	-	Life Cycle Cost Analysis
Solar PV	-	Solar Photovoltaic
CH_4	-	Methane
CO_2	-	Carbon Dioxide
tCO_2	-	Ton Carbon Dioxide
NEM	-	Net Energy Metering
FiT	-	Feed-in Tariffs
SAG	-	Smart Automation Grant
SELCO	-	Self-consumption
HOMER	-	Hybrid Optimization of Multiple Electric Renewable Energy
CAPEX	-	Capital Expenditure
OPEX	-	Operation Expenditure
UV	-	Ultraviolet
CV	-	Calorific Value
CAGR	-	Compound Annual Growth Rate
IRENA	-	International Renewable Energy Agency
GITA	-	Green Investment Tax
REEM	-	Registered Electrical Energy Manager
EMS	-	Energy Management Control System
ESM	-	Energy Saving Measures
SBR	-	Sequencing Batch Reactor
POME	-	Palm Oil Mill Effluent

CHP	-	Combine Heat and Power
LED	-	Light Emitting Diode
PP	-	Payback Period
AC	-	Alternating Current
DC	-	Direct Current

CHAPTER 1

INTRODUCTION

1.1 Research Background

Climate change has become a global concern over the decade and resulted aggressive commitments in energy integration to reduce greenhouse gas (GHG) emission. There are variety of effect on life on the planet due to climatic variation. The available technologies and emissions reduction options shall include to reach net-zero emission by 2050. By 2030, low-emission energy sources expected to rise to 50% as shown in below:

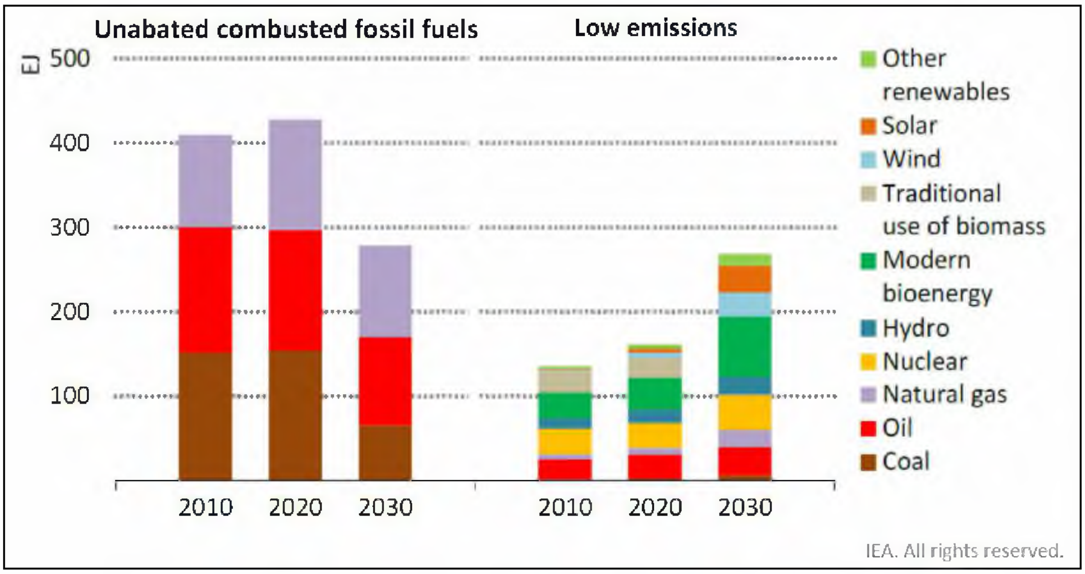

Figure 1.1 Low Emission Energy Supplies Sources Displaces Unabated Fossil Fuel by 2030 (IEA,2021)

Sewage treatment is the process of converting sewage into bilge water that can be discharged back to environment to prevent wasted. It is a facility with combination of processes that are used to treat the sewage and remove pollutant. It contains of high amount of chemical, hydrodynamic, and thermal energy that have potentially exploited for several uses. Sewage treatment plant (STP) are consuming high electricity consumption and it has locally potential to produces renewable energy by having high potential for heat generation, capability to produce biogas in the anaerobic digestion (AD) process. The overall process of the STP as shown in figure below:

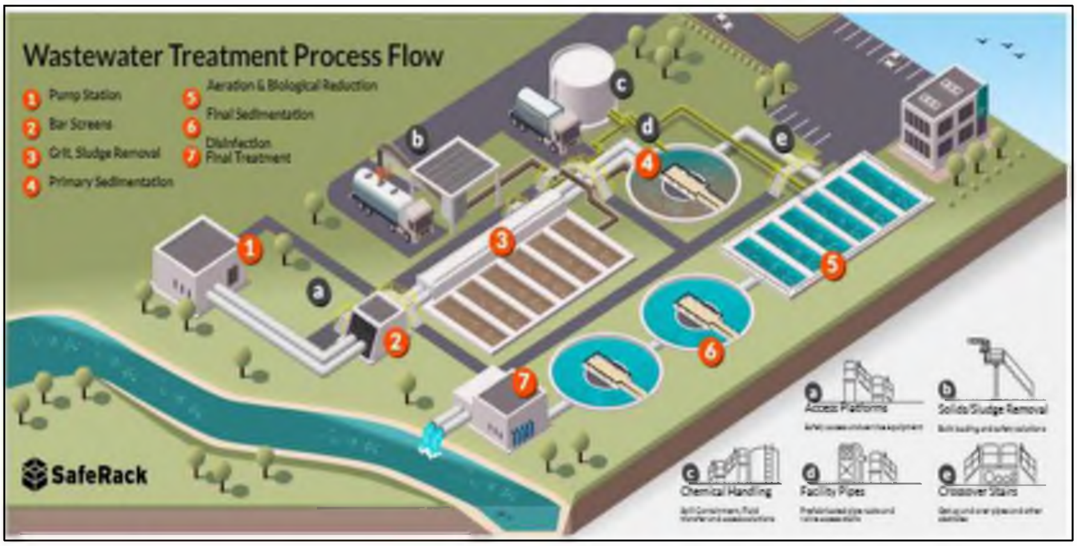

Figure 1.2 STP Process Flow Overview

STP energy consumption in a standard STP reported with mean value of 0.25-0.33 kWh/m³ (Pietro Elia, 2021) mainly consumed during the aeration process estimated 60% from total energy consumption. The pumping process estimated 13% of energy consumption while the sludge treatment contributes of 15% energy usage. Figure below shows the percentages of the energy consumption in standard or common STP.

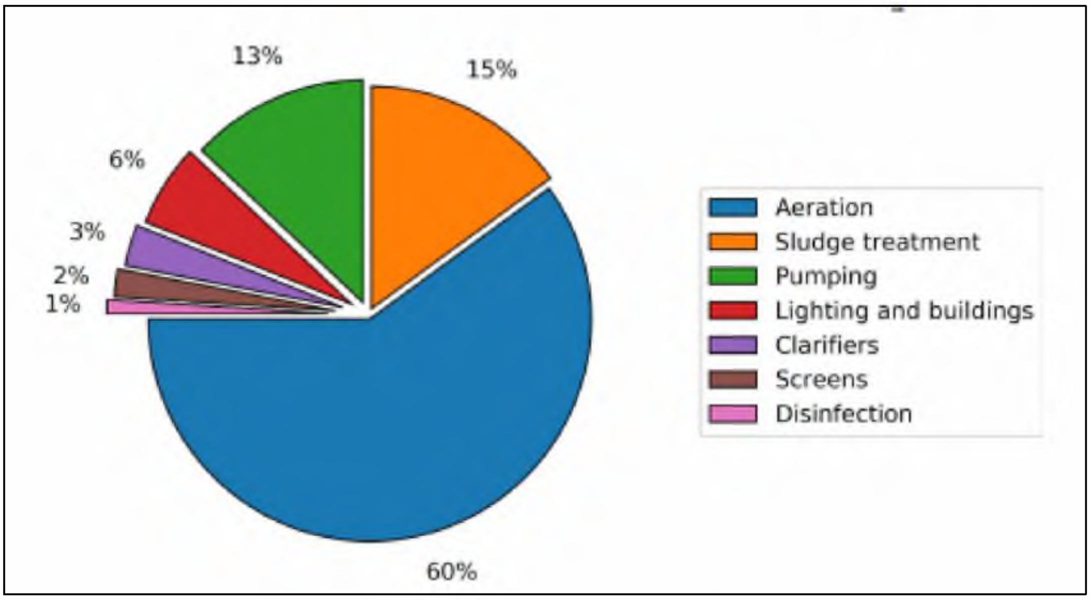

Figure 1.3 Energy Consumption in Standard STP

1.2 Problem Statement

Rapid urbanization and industrial growth for last 50 years have brought high standard of living, exhaustion of resources, loss of biodiversity, degradation of environment, pollution, and the threat of climatic agitation through greenhouse effect. The demand of treating STP led to development the number of processes in order to allow to minimize the pollution and to ensure the maximum or large quantities of water to be recirculated for various purpose. There is the surge of electricity demand when installation of new STP, increasing the cost for development and increase the energy demand. In other words, it will contribute to the high carbon emission directly. This study focusing on the sewage treatment plant at the residential area.

The STP result in large amount of indirect carbon dioxide emission by consuming a lot of power during the process. There is typical energy conservation and emission reduction technology available in the market in order to reduce the energy such as photovoltaic power generation, and sludge anaerobic digestion technology with a biogas cogeneration system.

Potential energy saving and process improvement with suitable methodology is important to identifying the suitable key energy consumption indicators for benchmarking and to compare with different STP. Current used treatment method is more to removing potential energy rather than recovered the energy for the potential of use even though there are 10 times amount of potential energy as the energy used to treat the sewage (Ele Greenberg,CEM). The economic, energy and carbon neutral analysis were established in order to propose the most potential improvement measures that can be apply in the STP.

1.3 Research Objective

The main purpose of the research is to evaluate the STP process and to propose the energy improvement measures and to optimizing the overall process of the STP. The objective that has been identified to attend as follows: -

- To analyze the profile for the STP process and proposed process improvement
- To propose the energy saving measures (ESM)
- To perform economic analysis for STP for all proposed improvement measured or method

1.4 Research Scopes

The research scope shall include:

- Perform literature review on the STP process and energy usage
- Carry out the improvement measured and the method to optimizing the overall process.
- Analyze the optimal improvement and solution in term of technical, commercial, and environmental aspects.

1.5 Significance of the study

Aeration process in the STP consumed the highest electricity consumption. Optimizing the overall process of the STP will lead to reducing energy consumption form the grid and contribute to reducing GHG emission. Installation of solar PV and re-used other waste to perform renewable energy is important to reduce electricity consumption from the grid. It will reduce fossil fuel consumption and ultimately mitigate the effects of climate change and global warming.

Sludge and gas produce from the STP also being re used back by doing analysis and process to produce as RE. Installation of solar PV is the best option to reducing electricity demand from the grid along with other ESM proposed in this research.

Hence, this study is to provide the energy saving measures, proposed the RE, and optimizing the overall STP. The feasibility study also being conduct and review.

REFERENCES

Ullah, K.R., R. Saidur, H.W. Ping, R.K. Akikur and N.H Shuvo (2013), 'A review of Solar Thermal Refrigeration and Cooling Methods', Renewable and Sustainable Energy Reviews, 24, pages 499-513.

Mohd Fairuz Abdul Hamid, Nor Azuana Ramli (2017) Energy efficiency strategy for sewerage treatment plant: A case study in Malaysia

Qunli Zhang, Yixiong Yang, Xinchao Zhang, Fang Liu, Gang Wang(2022) Carbon neutral and techno-economic analysis for sewage treatment plants

Sina Borzooei, Guiseppe Campo, Albert Cerutti, Lorenza Meucci, Deborah Panepinto,Marco Ravina,Vicenzo Riggio, Barbara Ruffina, Gerarda Scibilia, Mariachiara Zanetti (2019)

Optimization of the sewage treatment plant: From energy saving to environmental impact Joao Henriques, Justino Catarino (2017) Sustainable Value – An energy efficiency indicator for sewage treatment plants

Erin Musabandesu, Frank Loge (2021) Load shifting at sewage treatment plant: A case Study for participating as an energy demand resorce

Amarsinh L. Jadhav, Rajendrakumar V. Saraf, Aditya N. Dakhore (2021) Energy recovery from sewage treatment plant sludge

Pietro Elia Campana, Matia Mainardis, Allesendro Moretti, Mattia Cottes (2021) 100% renewable sewage treatment plants: Techno-eonomic assessment using a modelling and optimization approach

Paola Foladori, Francesco Vitali, Mentore Vaccari (2015) Energy audit in small sewage treatment plants: Methodology, energy consumption indicator, and lesson learned

Nor Azuana Ramli, Mohd Fairuz Abdul Hamid (2017) Analysis of energy efficiency and energy consumption costs: a case study for regional sewage treatment plant in Malaysia

Ely Greenberg, P.E., CEM Energy audits for water and sewage treatment plants and pump stations

Yanwen Shen, Jessica L. Linville, meltem Urgun-Demirtas, Marianne M. Mintz, Seth W. Snyder (2015) An overview of biogas production and utilization at full scale sewage treatment plant (STPs) in the United States: Challenges and opportunity towards energy-neutral STPs.

Part1: Electrical Energy Audit Guidelines for Building. Energy Commission (2016)

MS 1525:2007 Code of practice on energy efficiency and use of renewable energy for non-residential building (first revision)

Energy audit report guideline (industrial) . SEDA (2021-2025)

Shi, C.Y (2011) Mass flow and energy efficiency of municipal sewage treatment plant.

Metcalf and Eddy (2003) Sewage engineering treatment and reuse, 4^{th} edn. McGraw Hill

Yifan Gu, Yue Li, Xuyao Li, Pengzhaou Luo, Hongtao Wang, Xin Wang, Jiang Wu, Fengting Li (2017) Energy sel-sufficient sewage treatment plants: feasibilities and challenges

Milad Tamjidi Farahbaksh, Mahmood Chahartaghi (2020) Performing analysis and economic assessment of a combined cooling heating and power (CCHP) system in sewage treatment plants (STPs)

Bruno J. Cardoso, Eugenio Rodrigues, Adelio R. Gaspr, Alvaro Gomes (2021) Energy performing factors in sewage treatment plant: A review

D. Haralambopoulos, I. Pantelakis, P.Paraskevas, Th. Lekas (1996) Sewage treatment and renewable energy potential in the Aegean Island

Faegheh Moazeni, Javad Khazaei (2021) Co-optimization of sewage treatment plants interconnected with smart grid

Junwen Yang, Bin Chen (2021) Energy efficiency evaluation of sewage treatment plants (STPs) based on data envelopment analysis

Peng Yan, Hong-Xin Shi, You-Peng Chen, Xu Gao, Fang Fanf, Jin-Song Guo (2020) Optimization of recovery and utilization pathway of chemical energy from sewage pollutants by a net-zero energy sewage treatment model

Runxi Liu, Runyao Huang, Ziheng Shen, Hongtao Wang, Jin Xu (2021) Optimizing the recovery pathway of a net-zero energy sewage treatment model by balancing energy recovery and eco-efficiency

Michael Schafer, Oliver Gretzschel, Theo G. Schmitt, Henning Knerr (2015) Sewage treatment plants as system service provider for renewable energy storage and control energy in virtual power plants- A potential analysis

Farida Hanum, Lee Chang Yuan, Hirotsugu Kamahara, Hamidi Abdul Aziz, Yoichi

Atsta, Takeshi Yamada, Hiroyuki Daimon (2019) Treatment of Sewage Sludge Using Anaerobic Digestion in Malaysia: Current State and Challenges

Nathalie Bachmann, David Baxter, Gunther Bochmann, Nuria Montpart (2015) Sustainable Biogas Production in Municipal Sewage Treatment Plant

Eyob Habte Tesfamariam, Zekarias Mihreteab Ogbazghi, John George Annandale, Yemane Gebrehiwot (2020) Cost Benefit Analysis of Municipal Sludge as a Low-Grade Nutrint Source: A Case Study from South Africa

Nikolay Makisha, Daria Semenova (2018) Production of biogas at sewage treatment plans and its further application

Salaheddine Elmoutez, Almotasembellah Abushaban, Mohamed Chaker Necibi, Mika Sillanpaa, Jiadong Liu, Driss Dhiba, Abdelghani Chehbouni, Mohame Taky (2022) Design and Operational Aspect of Anaerobic Membrane Bioreactor for Efficient Sewage Treatment and Biogas Production