CHEMICAL ENGINEERING TRANSACTIONS
VOL. 122, 2025

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Jeng Shiun Lim, Bohong Wang, Guo Ren Mong, Petar S. Varbanov

ISBN 979-12-81206-23-6; **ISSN** 2283-9216

DOI: 10.3303/CET25122055

Quenerhiya: A Community-Centered Waste-to-Energy Complex in Payatas, Quezon City

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Quezon City Philippines confronts a serious challenge in administering the increasing quantities of Municipal Solid Waste (MSW) which resulted pollution, health hazards and safety concerns that prompted the termination of the Payatas dumpsite. This study intends to tackle the MSW management of the city by proposing a Waste-to-Energy (WtE) complex that turns MSW into energy. The objective of the study aims to assess the benefits of integrating waste management and energy generation, explore sustainable design strategies and innovations optimizing energy efficiency and minimizing impact, and applying architectural principles designing a WtE Complex. The methodology used in this study employed a qualitative, mixed-method approach using surveys and interviews with professionals in waste management, energy, and architecture to influence the design process. The design involves creating a facility that contains, processes, and converts waste into energy with spaces for waste delivery, storing, processing, boiling, heating, and energy-generation spaces. Key findings show that the WtE complex may be capable in processing an estimated 469,533.6 t of waste annually, generating 15 to 30 MW of electrical energy. This first large scale WtE complex in the Philippines may offer a sustainable model for waste management and energy generation in Quezon city.

1. Introduction

Municipal Solid Waste (MSW) has been a rising concern for Quezon City (NSWMC, 2023). With over 3.2 M residents as of 2024 (World Population Review, 2024), the city is expected to contribute to the projected 23,000,000 t of national MSW by 2025 (Mantaring, 2024), equating to over 7.87 M garbage trucks. The Quezon City Local Development Investment Program (QCLDIP) listed waste management as their priority for 2024-2026 (Quezon City Government, 2024). As waste production increase, so does energy demands. The study aims to investigate the environmental benefits of developing a WtE complex, along with the architectural considerations that may be applied and the innovations and technological approached that would be the most appropriate to support a clean energy source. This research proposes the development of Quenerhiya, an integrated waste management and energy generation complex in Payatas, Quezon City that uses WtE technologies to transform MSW into clean energy, to improve the quality of life for residents and support the city's long-term sustainability.

2. Review of Related Literature

The Philippines generates 61,000 t of waste daily, amounting to 16,630,000 t annually in 2020 to 24,000,000 t by 2045 due to population and industrial growth (Baclig, 2024). However, limited Material Recovery Facilities caused MSW to be incinerated or dumped, leading to air pollution (Simeon, 2021). Among the cities affected by these concerns is Quezon City, where population increase intensified crippling waste crisis with a 2% rise in population and is predicted to increase in the coming years (World Population Review, 2024). With a population of approximately 140,000, Payatas, a barangay in Quezon City contributes considerably to the city's waste output, averaging over 61,000t per day. According to the Comprehensive Zoning Ordinance of 2016, Payatas is in a Special Urban Development Zone (SUDZ) which allows the opportunity for resource recovery and waste management facilities. Given this zoning ordinance lies a chance to integrate an innovative solution presented by the WtE technology to improve waste management and energy generation as an effective option converting

Paper Received: 7 July 2025; Revised: 27 September 2025; Accepted: 3 December 2025
Please cite this article as: Gacutan W.G., Tejada A.P., Lagundi L.M.W., Herbosa J.T.A., Tolentino C.A., 2025, Quenerhiya: A Community-Centered Waste-to-Energy Complex in Payatas, Quezon City, Chemical Engineering Transactions, 122, 325-330 DOI:10.3303/CET25122055

waste into energy, reducing reliance on fossil fuels. Waste-to-energy technologies are divided into different types based on the process through which the waste is turned into energy: thermal only, which includes incineration, thermo-chemical, mechanical & thermal, and biochemical (Gergel, 2021). Current WtE technologies include Incineration, anaerobic digestion, gasification and hydrothermal carbonization (Khan, 2024). While WtE technologies differ in efficiency, cost, and environmental impact, these machineries aim to achieve a circular economy (Rezania et al., 2023). Incineration uses heat to burn MSW in an enclosed boiler, destroying waste while recovering material and energy. This releases harmful chemicals into the atmosphere that contribute to pollution (U.S. EPA, 2025). Meanwhile, Gasification process converts carbon rich waste into syngas, a renewable source of fuel that uses low oxygen in a closed plant, thus no burning is involved. (Santos, et al., 2022). Circular economy (CE) framework's integration of WtE focused on recovering energy from waste and lowering pollution through resource recovery and reuse which WtE plays a part by lowering the consumption of raw materials and resource efficiency (Tabibi, 2024). A study conducted by Magnanelli, et al. (2023) on MSW management in Oslo, showed impact of waste technologies in a circular economy. The study emphasized the role of advanced solutions in sorting and recycling in achieving EUs recycling goals for 2025-2030. In the case of developing nations in Asia, Thailand have started to model their waste management after China which leads the world in WtE capacity with the Nong Khaem plant in Bangkok which can process 500 t of solid trash per day (Wachapanich et al., 2022). In the Philippine context, various WtE schemes have been implement such as: Anaerobic digestion, landfill methane recovery, and combustion (Ogunjuyigbe, et al., 2017). These technologies may be costly, however, it could address the nation's energy and environmental problems if given the right backing (Anonas, et al., 2023). Despite these drawbacks, several nations have successfully developed applying WtE and circular economy in their waste management strategies. Barahmand and Eikeland (2022) examined gasification as a sustainable method for converting MSW into syngas and other by-products compared to methane-reformed hydrogen. Additional examination of Life Cycle Analysis (LCA) revealed that gasification emits less greenhouse gases compared to other processes like pyrolysis or landfilling, making it environmentally sustainable (Whitebell, 2020). Still, Social and economic challenges remain, including health risks from toxic gas exposure and the economic feasibility of hydrogen production. Quezon City faces a pressing challenge in managing its growing MSW, even with the establishment of MRFs, it is insufficient to combat the growing crisis of waste management. WtE technologies, particularly gasification, offers an ideal and promising solution due to their lower emissions and energy recovery with international examples such as Thailand’s Nong Khaem plant in Bangkok showing effective integration into circular economies. While the Philippines tackles social, economic, and regulatory hurdles, public perception remains positive due to its environmental benefits and sustainable solution. These findings prove the need for a localized, sustainable waste management strategies that align with sustainable development goals, most critically in underdeveloped areas like Payatas.

2.1 Innovations

Since the proposed facility deals with waste management, Odor removal technologies play an important role by limiting the impacts on gas emissions produced during waste handling and energy generation (Tornex Indoor Air Quality Solution Company, 2020). The most effective systems, Biofiltration and Activated Carbon Filtration, remove volatile organic compounds that eradicate airborne odors (Air-Scent International, 2021). The active phytoremediation wall system is a hydroponic based technology that is created to improve indoor air quality by filtering air through plant systems. This system works by introducing air outside via HVAC or natural ventilation into a duct that distributes across plant roots. The roots filter airborne toxins, particulate matter and other pollutants, purifying the air without harming the plants (Grozdanic, 2019). Community spaces within the WtE complex allow the community to interact while maintaining safety and security of the people. Additional community spaces include parks, recreational areas, educational institutions that foster education and recreation within the complex.

2.2 Case Study

Case studies in the Philippines such as All Waste Services Inc. (All Waste Services Inc., 2021), Isabela Biomass Energy Plant (JobStreet, 2024), and San Carlos Biopower (Lloyd, 2024) offer options on waste management. These facilities provide waste conversion to energy and recover resources from waste material which focuses on waste treatment and disposal, biomass combustion, methane capture, and burning. International case studies such as the Copen Hill Energy Plant & Urban Recreation Center (Pintos, 2024), Waste-to-Energy Campus (INI Design Studio, 2024), DH Palencia Biomass Plant (Caballero, 2024), and The Asahi Clean Center(Satiada and Calderon, 2021),) share the purpose of aiming to reduce landfill waste and generate energy from waste through Thermal waste treatment technologies focusing on architectural innovation from community-centric architecture.

Table 1: Comparative analysis of Innovations

Innovation	Conventional approach	Proposed innovation	Justification/Advantage
Odor Management system	Basic ventilation or chemical masking	Biofiltration and Activated Carbon Filtration	Environmentally safe, energy-efficient, and removes VOCs
Indoor Air Quality Management	Mechanical HVAC filtration alone	Active Phytoremediation Wall System	Filters air through plants improving indoor air quality
Community Engagement & Integration	Perimeter fencing with restricted access to WtE facilities	Inclusion of parks, education spaces, and public areas	Promotes community trust, environmental education, and social inclusion
Environmental Co-benefits	Focus mainly on waste reduction or energy recovery alone	Integration of green technologies and public spaces	Advances circular economy and multi-functional land use

3. Methodology

A qualitative research approach and a phenomenological research design were used in the study to have a better understanding of the lived experiences of the residents, while the phenomenological design enabled the researchers to learn about their preferences, behaviors, and particular needs concerning waste management. The data gathered from the respondents are relevant to the field of architecture relating to the context of sociocultural, psychological, and personal preferences acquired from the respondents. The participants involved residents in Payatas, Quezon City, NCR, engineers, architects, and officials from government agencies. The researchers utilized simple random sampling and reached a sample size of ninety-five (95) respondents. A flexible set of open-ended questions was prepared to guide discussions with industry experts and government officials. The interview questions attempt to explore the preferences, needs, and expectations of the respondents with regard to the Waste-to-Energy project.

4. Results and Discussions

A survey was conducted among Quezon City residents to gather insights on a proposed Waste-to-Energy (WtE) generation complex. The 95 respondents, representing all six districts, were primarily young adults (18-29 years old), with students comprising nearly half (49.5 %) of the participants. The survey aimed to understand residents' familiarity with WtE concepts, identify existing waste management challenges, and explore potential impacts and design preferences for the proposed complex. The survey showed that the most common waste issue in the city is illegal dumping and littering (29.9 %), followed by the lack of public awareness and education on proper disposal and segregation (26.1 %). Relevant concerns include the lack of insufficient waste collection and disposal facilities (17.5 %) and limited public funding and resource allocation (17.2 %). Despite this, respondents showed positive feedback. The government of Quezon City along with its residents responded positively to the proposed WtE complex believing a WtE facility could significantly reduce landfill usage by converting solid waste into energy and diverting waste from traditional disposal methods. The facility is designed around advanced waste conversion systems with the design going beyond conventional facilities by incorporating biophilic features, public spaces, recreational zone, and research center. Additionally, its potential for job creation, economic development, and improvement of life in the community is well received as it will further improve the quality of living for the residents of Payatas.

4.1 Functionality

Faced with escalating waste generation and inadequate disposal facilities due to rapid urbanization in Payatas, Quezon City, Quenerhiya proposes an innovative solution by integrating Waste-to-Energy (WtE) technologies. This initiative aims to convert Municipal Solid Waste (MSW) into usable energy, directly addressing the growing waste problem. Beyond waste conversion, Quenerhiya seeks to redefine urban living by incorporating green spaces and fostering community inclusion, leveraging architecture to transform negative perceptions of waste into a positive experience. This approach, which includes community and educational spaces, aligns with the city's development goals for waste management and green infrastructure by presenting waste as a valuable resource rather than something to be avoided.

The Gasification process works by heating MSW collected through a feed bin and transported via conveyor belt to the gasifier reactor where the feedstock (MSW) undergoes drying, pyrolysis, oxidation, and reduction. This Results in syngas formation comprised of CO_2 (8~12 %), H_2(15~20 %), $CH4$ (~3 %), CO (15 %), N_2 (45~50 %), tars and particulates. The syngas then goes through the filtration process that utilizes a cyclone to separate coarse particles and ash from the raw gas that is boosted by fans through a system. It then goes through a hot air heat exchanger to preheat incoming air. After leaving the cyclone, it proceeds to the air coolers to remove tar and water droplets in the gas stream. The purified syngas is then stored on a buffer tank to supply the gas that powers the generator sets, turning mechanical energy into electrical energy.

Figure 1: Aerial Perspective

Table 2: Powermax gasifier plant technical specifications

Model	2000TFBG – Twin-Fire Fixed Bed Gasifier
Biomass Size and Moisture Requirement	20~80mm x 10~80mm with 20 % wet basis of moisture
Biomass Consumption (Kg/Hr)	2000-4000
Gas Production (Nm^3 /h)	5000-6000
Ash Moisture Type	Dry ash / Wet ash type
Type of Gas Purification	Dry Type Gas Purification System
Heat Value of Gas	1,200 Kcal/Nm^3
Gas Composition	CO_2 (8~12 %), H_2(15~20 %), CH_4(~3 %), CO (15 %), N_2 (45~50 %)

The formula in getting the energy output of one single gasifier plant begins with energy input. The daily waste generated by the Districts of Quezon City is around 1,141.88 t. The average calorific value of MSW in Metro Manila is 7.65 MJ/Kg. according to (Anonas, et al., 2023), we can compute the Energy Power Potential using this Eq(1):

$$EPP\ MSW = LHV\ MSW\ \frac{1000\ kg}{1\ tonne} \times \frac{Weight\ MSW}{24\ h} \times \frac{1\ kWh}{3.6\ Mj} \times 35\ \%\ energy\ conversion\ efficiency \quad (1)$$

$$EPP\ MSW = LHV\ MSW\ \frac{1000\ kg}{1\ t} \times \frac{1141.88\ t}{24\ h} \times \frac{1\ kWh}{3.6\ Mj} \times 0.35 = 30{,}331.18\ kW \sim 30\ MW.$$

Most Gasifier plants have an energy conversion efficiency of 35 %. Thus, the Total energy output that may be able to produce is around 30,331.18 kW, roughly 30 MW.

4.2 Site Development, Buffer and Zoning

The project is measured with 148,672.00 m^2 (approximately 14 hectares) located in District II, Payatas, Quezon City situated in a Special Urban Development Zone. The lot is directly facing Payatas Road, one of the two major roads leading to Rizal and Montalban landfill, facing a major road passed by Waste collection vehicles. The design of the Waste-to-Energy complex has been carefully zoned and buffered with the focus of protecting nearby residents while still offering public access and other environmental amenity. The 100-meter plant buffer encircling the site was used to mitigate noise and odor emissions conforming to the Direct Impact Area (DIA) requirements of DAO 2003-30 to lessen noise, odor, and visual impact. Additionally, the site is also divided into three zones starting with the Green Zone which comprised the largest area that is open to the public including parks, playgrounds and transportation hubs. Next is the Yellow Zone for semi-public access that is heavily landscaped which serve as an ecological buffer with more stringent monitoring for activities. The core lies the Red Zone which is for restricted use for authorized personnel and scheduled educational visits only.

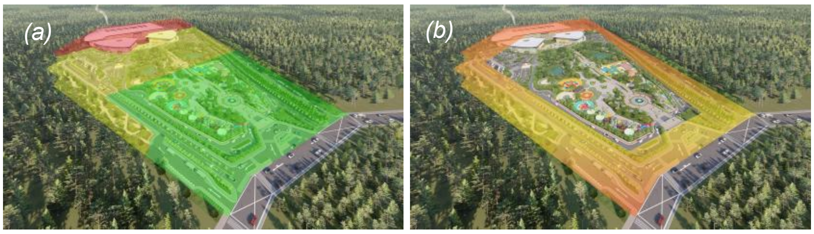

Figure 2: 100 Meter Site Buffer (a) and site zoning (b) for the overall security within the WtE Complex

Public shuttles, bicycle paths, and pedestrian walkways are incorporated into the design of the site to ensure efficient movement while clearly distinguishing public, semi-public, and restricted areas. Efficiently placed parking areas are also integrated with direct connections to major facilities. Security features are strategically placed throughout the site such as security cameras, toll gates, information kiosks, and informative signage in public and semi-public zones for enhanced visitor wayfinding. Finally, the restricted Red Zone has enhanced security protocols, including temperature indicators, smoke detectors, air pollution control systems, biometric and keycard access, and designated checkpoints for waste collection vehicles.

4.3 Sustainability

The complex's design integrates sustainable approaches aimed at national and community enhancement, a result of collaborative efforts with major Philippine government agencies such as the Department of Energy (DOE), the Energy Utilization Management Bureau (EUMB), and the Department of Sanitation and Cleanup Works for Quezon City (DSQC). This design aligns with multiple United Nations Sustainable Development Goals (UNSDGs), specifically addressing No Poverty, Affordable and Clean Energy, Industry Innovation, and Infrastructure, Responsible Consumption and Production, Quality Education, Decent Work and Economic Growth, Sustainable Cities and Communities, and Climate Action.

5. Conclusion

For the first objective, the design of the waste-to-energy complex was able integrated environmental sustainability through the incorporation of waste segregation facilities, by-product recovery systems, and gasification technology capable of generating 15 MW. Green spaces and native vegetation were strategically placed to improve air quality and serve as buffer zones between industrial functions and residential areas. For the second objective, key architectural principles were established to ensure functional efficiency while minimizing public exposure to industrial processes. This was achieved through the strategic zoning of industrial, community, and educational areas, along with the incorporation of passive design strategies such as natural ventilation and daylighting to reduce overall energy demand by approximately 300,000 to 350,000 kWh annually for the facility, based on operational benchmarks for industrial complexes in tropical climates. For the final objective, sustainable design strategies and innovations to optimize energy efficiency and minimize environmental impact was achieved through the integration of gasification technology which can produce 15 MW. The complex allocates up to 1.5 MW of electricity to power the whole site, while the remaining would be supplied to the local power grid as a form of Renewable Energy Certificates (RECs). Incorporation of sustainable materials with high thermal performance for insulation, odor removal technology, and lastly rainwater harvesting systems to support non-potable water usage. Native vegetation and semi-permeable surfaces were used to reduce heat absorption and promote water infiltration in selected zones.

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