Application of Green Engineering Towards Sustainable Development in Sub-Urban Areas in Luzon

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***Abstract* – Urbanization is inevitable in all emerging societies. However, Green Engineering design must be promoted to attain sustainable development. This research concentrated on examining specific suburban areas as part of the city's sustainable development initiatives, which involve leading projects employing green engineering solutions. Two cases were presented, one was located at Santa Rosa, Laguna, and the other one was located at Canaman, Camarines Sur. In the case of Santa Rosa, Laguna, several green engineering projects have been implemented, while in Canaman, Camarines Sur, green technology adoption is limited, despite plans for future implementation. As a recommendation, a more aggressive policy towards providing incentives for establishments with certification for green buildings was advised. Also, even though the city has a master plan for a bicycle lane to promote alternative modes of transport, it is also advised to come up with a more reliable public transport system. Aside from that, more training and seminars on the awareness of green engineering approach can be included and eventually be part of their program for sustainable development. Overall, it is imperative for the national government to address the specific underlying issues identified in suburban areas such as Santa Rosa, Laguna, and Canaman, Camarines Sur. Moreover, comprehensive support is needed to assist these cities in implementing green engineering projects and advancing toward sustainable development goals.**

***Keywords* — Green Engineering, Sustainability, sub-urban development, green technology**

I. Introduction

DUE to the exponential rise in the world's population, global warming, degradation of the environment, and urbanization, it has become apparent that engineering design or application of green engineering must be promoted to attain sustainable development. Green engineering focuses on the design, use, and commercialization of products and processes with the aim of reducing pollution while promoting sustainability and minimizing risk to human health and the environment, without the need to sacrifice economic efficiency and viability [1]. The early application of green engineering in the design and development phase of a product or process encompasses the concept of producing the greatest impact and cost-effectiveness in the decision to protect human health and the environment [1].

As the city starts to urbanize from its rural state, converting "natural" land such as forests for residential or commercial use drastically changes its hydrological characteristics [2]. Through the city's development, natural lands were converted into rooftops, driveways, parking lots, roadways, and sidewalks. Development negatively impacts the environment as many of the new materials and components used in land development contribute higher pollutant loads while the natural filtering action of wild vegetation (trees, bushes, tall grasses) is replaced by concrete, asphalt, and rooftops, which offer little means for sustainable development [2].

Fig. 1. Common Challenges During Implementation of Smart Cities

The main objective of this research is to investigate whether current applicable green engineering design trends were being applied in the selected Sub-Urban Areas towards sustainable development. Specifically, it seeks to address the following: (1) evaluate the extent of application of applicable green engineering design on projects located at the selected sub-urban areas towards sustainable development. (2) conduct a case study comparing selected sub-urban cities and how each of them addresses their sustainable development growth.

II. Green Engineering

Green Engineering approaches the design of goods and processes to achieve one or more of the goals by applying financially and technologically feasible principles follows: (1) reducing the amount of pollution generated by the construction or operation of a facility, (2) decreasing the human population's exposure to potential hazards (including reducing toxicity) (3) the volume of pollution created by the construction or operation of a facility performance and viability [4].

Anastas and Zimmerman [5] defined the following twelve principles of green engineering design:

a. designers need to strive to ensure that all material and energy inputs and outputs are as inherently nonhazardous as possible;
b. it is better to prevent waste than to treat or clean up waste after it is formed;
c. separation and purification operations should be designed to minimize energy consumption and material use;
d. products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency;
e. products, processes, and systems should be output-pulled rather than input-pushed through the use of energy and materials;
f. embedded entropy and complexity must be viewed as an investment when making design choices on recycling, reusing, or disposing;
g. target durability, not immortality;
h. design for unnecessary capacity or capability solutions should be considered a design flaw;
i. diversity in multicomponent products should be minimized to promote disassembly and value retention;
j. design of products, processes, and systems must include integration and interconnectivity with available energy and materials flow;
k products, processes, and systems should be designed for performance in a commercial afterlife;
l. material and energy inputs should be renewable rather than depleting.

The application of green engineering in building infrastructure refers to the application of providing improvement that focus on being responsible to the environment and sustainable. It is applied throughout a building's life cycle starting from conceptual design, construction, operation & maintenance, renovation (if any), and demolition. Green engineering normally requires close collaboration between the contractor, architects, engineers, and the client at all project stages. Green engineering or green building practice expands and complements the usual building design concerns of, utility, durability, economy, and comfort. In doing so, it focuses mainly on factors involving environmental sustainability, social sustainability, and economic sustainability [3].

When it comes to Sustainable development that can be applied in a sub-urban setting, the best practices framework revolves around the following concepts described at the Institute of Local Government: (1) *energy Efficiency & Conservation,* and (2) create an Audit and assessment system to identify opportunities and benchmark energy usage of major agency buildings [6]. Likewise, establish an internal policy and procedure for promoting energy efficiency and conservation. It is also advised to work with businesses, homeowners, and energy providers. (2) *Water & Wastewater System:* Ensure water efficiency in agency buildings and operations and reduce water use in parks and landscapes. Promote Water conservation and address future water security. Likewise, create a safe and efficient water and wastewater system while promoting water recycling. (3) *Green Building*: Provide incentives for buildings and establishments that will seek certification focusing on the promotion of a greener environment. (4) *Waste Reduction & Recycling*: Reduce, Reuse, and Recycle motto. (5) Climate-Friendly Purchasing: Local agencies can have a significant impact on the environment since they are considered large consumers when it comes to purchasing goods and services. They can remain fiscally responsible while promoting practices that conserve natural resources by purchasing products or procuring services that reduce greenhouse gas emissions relative to competing goods and services. (6) Renewable Energy & Low-Carbon Fuels: Initiate a solar project of methane recovery programs and project while promoting fuel-efficient and alternative fuel vehicles. (7) Efficient Transportation: The emission of greenhouse gases can be limited by providing an efficient transportation system that includes promoting ride-sharing as an alternative to single occupancy vehicles and reducing travel distance. This can also help in the improvement of air quality, conservation of fuel and its cost, reduction of traffic congestion and make streets safer for pedestrians, bicyclists, transit users, and motorists [6]. (8) *Land Use & Community Design*. A balanced community with a well-planned location for

houses, schools, shops, job opportunities, and recreational activities can help reduce the frequency of trips. This will limit the time for driving if there is an option to walk, use bikes, and transit, and the emission of greenhouse gasses can be lowered. Also, this will encourage physical activity and a sustainable community with vibrant and healthy living. (9) *Open Space & Offsetting Carbon Emissions:* Agricultural lands, forests, open spaces, and parks act as "carbon sinks" by keeping emissions of greenhouse gasses, as well as being a place for recreational activities of the community [6]. (10) *Community & Individual Action*. The provision of objective and reliable information about the possible responses, impacts, and causes of climate change can help the residents be aware of the occurrences and empower them to make a difference and act.

As for the green building practices, some of the seven popular green building practices in 2021 according to Matthews [7] include (a) Net-zero Buildings or the concept that energy consumption should be roughly equal to its output; (b) Climate resiliency; (c) Green Star Certification; (d) LEED Certification; (e) Distributed Energy Systems or Building Management System; (f) EDGE Certification that stands for Excellence in Design for Greater Efficiencies; and (7) Alternative building materials. Current green engineering design trends of using alternative building materials include the usage of bamboo, recycled plastic, wood, and "green" paint.

III. Methodology

It focused on the identification, analysis, and generalization of green engineering practices that can balance sustainability while at the same time enhance the environmental condition of the selected sub-urban areas in the municipalities of Canaman, Camarines Sur and Santa Rosa, Laguna. Those suburban areas were strategically selected in consideration of their proximity to nearby urban cities. To achieve the objective of the study, the case study research method was used to provide a detailed and in-depth contextual analysis of a limited number of event conditions and their relationships [8]. A defined process mentioned by Yin [9] can be undertaken in this research to create a valid case study based on methodological guidelines, as follows: (a) Determination and definition of the research questions, (b) Selection of the cases and determination of data gathering and analysis techniques, (c) Collection of data, and (d) Evaluation and analysis of data.

A set of criteria was developed based on the focus of the study to attain the purpose of identifying the sub-urban areas that support sustainable green engineering practices towards sustainable development. These include the following: (1) level of urbanization; (2) existing and proposed green infrastructure projects and (3) policies supporting sustainable development. A systematic approach was developed to gather data from the stakeholders in these defined sub-urban locations to collect information from different sources as part of the case study. First, data was collected from the local government units concerning the green engineering practices implemented in the last five years. Then, design and data for green engineering were solicited from the engineering office as well as from the contractors involved in the design and construction of the projects. As part of the analysis, these cities were evaluated to determine if they were implementing best practices in green engineering aligned with the country's sustainable development policy.

IV. Case Study Analysis

A. Case I: Municipality of Santa Rosa, Laguna

The City of Santa Rosa is considered a first-class city in the province of Laguna, Philippines. According to the 2015 census, it has a population of 353,767 people, making it the second largest local government unit in Laguna after Calamba City. Santa Rosa is known for having industrial estates such as the Coca-Cola Plant and Toyota Motors. It is also popular because of the Enchanted Kingdom, a local theme park, and several housing developments by which most of its residents work in the urban cities nearby. Located west of Laguna de Bay, Santa Rosa's land area is approximately 5,543 hectares [11]. For sustainable development, the analysis aims to investigate the city's implementation level based on the recommended sustainability development framework. On Energy Efficiency and Conservation, one of the City's efforts for promoting stating is by issuing Ordinance 1720 s. 2011 section 31, promotes energy-saving practices in every establishment to put in place and encourage the shift to energy-saving measures such as efficient lighting systems, daylight-saving time, utilization of solar and wind energy, and anti-idling in parking areas. To put up a low-cost water facility, "One Water and Wastewater System" under the Philippine Sanitation Alliance Project Water was initiated in the city with the help of the United States Agency for International Development [12]. For Green building, notable land developments such as Nuvali and Greenfields can be observed that promote green building. Likewise, the new Santa Rosa City College upon completion will cater to a Leadership in Energy and Environmental Design (LEED) certification rating. Also, for waste management, the city is currently finalizing a 10-year Solid Waste Management Program that is now for approval by the National Solid Waste Management Commission [12]. To reduce the emission of greenhouse gases and ensure the quality of air, the city started to implement the "Carbon Shed Project" with the

aid of the Laguna Lake Development Authority and the World Bank [12]. Also, SALAIDA_IDA and Kummon Enkopping in Sweden assisted the city in the construction of "Ecological Sanitation Toilets" in public schools [12]. In terms of Efficient Transportation to provide a walking environment that is safe for pedestrians, the Santa Rosa Greenway Project is currently being implemented as one of the projects in the city. This will give a landscape that would be pleasing to people thus lessening noise, air pollution, and traffic congestion [13]. Lastly, as part of community and individual action towards sustainable development, activities such as regular river and lakeshore clean-up, tree planting, canal de-clogging, and street sweeping are being initiated in the city [12].

B. Case 1I: Municipality of Canaman, Camarines Sur

Canaman is a fourth-class municipality in the central part of the province of Camarines Sur [14]. The town is a landlocked area topographically situated on the estuarine floodplain along the low-lying areas on the northern and western sides of the bank of the Bicol River and on the east by Naga City. The low elevation and its location expose Canaman to some risks such as flooding, sea level rise, and tsunamis.

The major economic activities in the municipality are agriculture, retail trade, and services. The 2014 Community-Based Monitoring System Survey showed that the level of urbanization in Canaman is at 79%.

Infrastructure projects relating to the environmental protection of the municipality for the last five years include the construction and rehabilitation of Canaman flood control and drainage systems, the construction of rainwater collector systems, and the construction of slope protection. The municipality is constantly spearheading activities like tree planting, river clean-up, and canal de-clogging as part of their drive towards a clean environment.

However, solid waste management is a continuing challenge in the municipality. The ten-year solid waste management plan needs completion, review, and update to have a cohesive Solid Waste Management system. This includes a need to strengthen barangays to perform their function in the process and a need to strategize compliance with a sanitary landfill requirement.

As indicated in their vision – reality gap analysis as part of their Comprehensive Development Plan in 2017 – 2019, mentioned that one of their success indicators is a typhoon-resilient public and private building and housing, however, the current reality is that the presence of houses made of light/makeshift materials and old/dilapidated buildings are evident in their municipality. To bridge the gap of lack of funds and human resources and equipment, the local government unit envisions having land banking for resettlement and housing programs and funding for the study, design, and strict implementation of the National Building Code. Also included in their development plans is the research and adoption of climate-resilient designs and green designs. As part of their strategies, they prepared local shelter plans and formed linkages and partnerships with National Government Agencies and organizations and other business organizations.

Also included in their programs and projects are the formulation of a local shelter plan, riverbank/slope protection program, comprehensive drainage, and flood control program, government buildings and parks improvement program, formulation of comprehensive irrigation program, disaster and climate change resilient support infrastructure program [15].

In 2019, officers of the Local Government Unit of Canaman, Philippines, were trained to use the Bicol State College of Applied Sciences and Technology (BISCAST) Low-Cost House Building Technology. This training enabled them to construct an emergency shelter that year. The Climate Change Resilience (CCR) of this technology is achieved through adherence to green building standards. The technology was first used for the Climate Change Resilient Pilot House (CCRPH) as part of the BISCAST project, which aimed to innovate housing technology. Inaugurated in June 2016, this project represents an alternative approach to conventional construction for affordable social housing. It applies low-cost housing technology and utilizes climate-adaptive and energy-efficient devices. The CCRPH is built using environment-friendly construction technologies such as prefabricated beams and hollow blocks.

V. Results and Discussion

Suburban communities in general terms tend to be the most affluent, enjoy the highest socioeconomic status when ranked with rural and urban populations. They often have more job opportunities than rural areas, though maybe not as many as urban areas. In the Philippines, suburban areas like Santa Rosa, Laguna enjoy this level of opportunities and socioeconomic status through the presence of economic zones and premier developers investing in the growth of the city. Compared to urban areas like Metro Manila, a city needs to adopt the principle of low-impact development through the application of green engineering as the city becomes urbanized. In the case of Canaman, Camarines Sur, development is mainly saddled due to its geographical location as surrounding towns were mostly rural areas. It is also believed that some of the technologies being adopted in other sub-urban areas that are located away from urban cities were not being adopted due to limitations

in information technology and infrastructure. Many green building technologies focusing on energy conservation, water conservation, sustainable materials, and indoor air quality management have been developed. However, these technologies often do not reach suburban areas far from urban centers. In contrast, some suburban areas near urban cities are already adopting sustainable innovations.Table 1 shows the summary of the evaluation conducted to determine the extent of implementation of selected Sub-Urban Areas based on the suggested Sustainability Development framework by the Institute for Local Government. The evaluation is based only on assessing whether a program, policy, or project is being implemented in the selected city or not.

It shows that those suburban areas near the urban cities have programs aligned to the recommended sustainability development framework while areas that were located far away from the urban cities lack programs or initiatives to support the drive for sustainable development. While the importance of sustainable development is clear, it is also crucial to understand the issues suburban cities face that hinder the implementation of related programs. The first issue was the lack of financial resources to carry out projects for sustainable development. The presented cases justify this argument if we compare both cities in terms of their budget allocation. The second issue was natural calamities, such as typhoons or tsunamis, which can pose a threat to sustainability as they can destroy certain elements of infrastructure that were being built are located at high risk areas. The third issue was the conflict of priorities between immediate profit and investment towards sustainable technologies. In the case of Santa Rosa, Laguna as the city income grows exponentially due to the presence of economic zones, the city can concentrate its priorities towards investing in green infrastructure. Canaman, Camarines Sur on the other hand, focuses more on utilizing its funding to prioritize projects addressing problems of the city. The last issue would be the lack of effort at the city level, which can be observed in the case Canaman, Camarines Sur.

VI. Conclusions

In the municipality of Santa Rosa, Laguna a solid road map towards achieving sustainability development was already crafted. Likewise, new developments within the city emerged to promote a sustainable environment that people will enjoy while escaping from the metro as many of them work in nearby urban areas. For Canaman, Camarines Sur which was far away from the metropolis, practice for green technology was limited due to limitations in information technology and infrastructure. although there are laid plans soon.

As a recommendation, it is advised that Santa Rosa City, Laguna should focus more on providing alternative energy sources such as solar farms and windmills since the city is near Laguna de Bay. Also, to attract more businesses that will implement green-engineered buildings, more aggressive policies is suggested such as tax incentives and more stringent implementing rules and regulations for its local green building code in compliance with the Philippine green building code. In terms of transportation, as the city progresses, it is apparent to promote alternative modes of transportation such as putting up a dedicated bicycle lane

TABLE I

Level of Implementation of Selected Sub-Urban Areas based on the suggested Sustainability Development Framework

10 – Sustainability Development Framework		City of Santa Rosa, Laguna	Canaman, Camarines Sur
		Implemented / Not Implemented	
1	*Energy Efficiency & Conservation*	Implemented	Not Implemented
2	*Water & Wastewater System.*	Implemented	Implemented
3	*Green Building.*	Implemented	Implemented
4	*Waste Reduction & Recycling*	Implemented	Implemented
5	*Climate-Friendly Purchasing.*	Implemented	Not Implemented
6	*Renewable Energy & Low-Carbon Fuels*	Implemented	Not Implemented
7	*Efficient Transportation*	Implemented	Not Implemented
8	*Land Use & Community Design*	Implemented	Implemented
9	*Open Space & Offsetting Carbon Emissions.*	Implemented	Not Implemented
10	*Community & Individual Action.*	Implemented	Implemented

as well as strengthening its public transportation system. Lastly, engagement with the community is also advised to boost water segregation campaigns, tree planting activities, and canal de-clogging. In the case of Canaman, Camarines Sur, more training and seminars must be given to the leaders of the community to improve their awareness of the green engineering approach and eventually be part of their program for sustainable development.

Overall, as a holistic approach, the national government should address the lack of financial resources that prevent suburban areas from supporting green engineering projects and achieving sustainable development.

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