**CIGGAJ-PET: Pneumatic PET Bottle Compressor Using Solar Energy and Arduino Control**



Agustin, Gabriel Reign V.

Balarias, Ivan John B.

Lim, Joseph Julliane M.

Colinares, Ciara Jane B.

Piquero, Ma. Albert Grace W.

Division of Malaybalay City

Bukidnon National High School

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**Chapter 1**

**The Problem**

**Background of the Study**

The worldwide increase in plastic waste, especially from single-use plastic bottles, presents a serious threat to the environment. Reports indicate that millions of tons of plastic waste are deposited in landfills and oceans each year, leading to pollution, endangering wildlife, and worsening climate change. Although recycling is often promoted as a solution, its effectiveness is diminished by obstacles such as improper sorting, inadequate transportation, and the low volume-to-weight ratio of plastic bottles, which complicates waste management processes.

Unlike general trash, green and recyclable waste must be classified and separated according to their respective types due to specific reprocessing methods employed for each. As a result, the growing stockpile of this categorized waste will fill up the transportation space before it can be sent to the respective facility. Indeed, to address this issue effectively, the industry has introduced a practical solution by developing a trash compactor. A trash compactor is a machine designed to compress and reduce the volume of solid waste, including household garbage and industrial waste, making it more efficient to handle, store, and transport (Ramli et al., 2024).

A trash compactor is a mechanical device invented to reduce the volume of trash, making it suitable for use in various scenes such as domestic, public, and industries. Utilizing this kind of machine provides significant benefits in the waste accumulation system, as it allows for more efficient waste management by compacting the trash, enabling larger quantities to be collected at once (Ramli et al., 2024)

[Polyethylene terephthalate](https://www.sciencedirect.com/topics/chemical-engineering/polyethylene-terephthalate" \o "Learn more about Polyethylene terephthalate from ScienceDirect's AI-generated Topic Pages) (PET) is a widely used polymer in various industries due to its excellent physical and chemical properties. However, the increasing use of [PET](https://www.sciencedirect.com/topics/materials-science/polyethylene-terephthalate" \o "Learn more about PET from ScienceDirect's AI-generated Topic Pages) has also led to a global crisis in [waste management](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/waste-management" \o "Learn more about waste management from ScienceDirect's AI-generated Topic Pages), as the improper disposal of [PET](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/polyethylene-terephthalate" \o "Learn more about PET from ScienceDirect's AI-generated Topic Pages) products has caused significant environmental damage (Kibria et al., 2023). PET is a major source of accumulated waste in landfills, and to address this issue, recycling methods have evolved (Joseph et al., 2024). [PET](https://www.sciencedirect.com/topics/pharmacology-toxicology-and-pharmaceutical-science/polyethylene-terephthalate" \o "Learn more about PET from ScienceDirect's AI-generated Topic Pages) has become an essential material in modern-day society (Sarda et al., 2021). The recycling of PET is crucial in mitigating this crisis, as it can significantly reduce the amount of plastic waste that ends up in landfills or oceans. PET recycling involves collecting used PET products, processing them into new materials, and then using them to manufacture new products (Joseph et al., 2024).

Arduino is an open-source programmable board. It is very easy to use and powerful single board computer that has gained considerable traction in the hobby and professional market. It consists an Integrated Development Environment (IDE) where one can write and run the programs and these programs are known as sketch in arduino and microcontroller (Kaswan et al., 2022).

Pneumatic uses an air compressor to reduce the volume of air in order to increase its pressure. This then passes through a filter into a pneumatic tube, where it is checked by valves before reaching an actuator that does the job at the end of the process. It could be a cylinder or a device that performs a function, such as lifting, moving or gripping. They are generally used with smaller loads as pneumatic systems produce less force than hydraulic systems and, since the air is easy to compress, pneumatic can absorb excessive shock (Waircom, 2020).

S**olar-powered trash compactors** are an innovative waste management solution that come equipped with a solar panel, a battery, compaction machinery, sensors and monitors. They are designed to increase the efficiency of waste management by **compacting waste collection**, and reducing collection frequency and carbon emissions through solar power. The **solar powered garbage compacter** minimizes the volume of waste, leading to better space utilization within the bin. Fewer collection cycles translate directly to positives like fewer miles travelled, fewer working hours, reduced fuel costs, and less frequent vehicle maintenance. All of these factors cumulatively contribute to massive savings of up to 80% for corporations and **waste management service providers** (Sab Tech, 2024).

The researchers aim to develop an innovative and sustainable solution to address the growing issue of plastic bottle waste. It seeks to create an efficient system that compresses plastic bottles, significantly reducing their volume to simplify storage, transport, and recycling. By integrating solar energy as the primary power source, the ECO-BIN not only promotes the use of renewable energy but also minimizes the environmental impact associated with traditional power consumption. Additionally, the system leverages Arduino technology to automate and optimize the compression process, durability, and user-friendly operation.

Thus, the researchers aims to encourage more sustainable waste management practices, reduce the strain on landfills, and foster environmental awareness among communities. This highlights the potential of combining modern technology and eco-friendly energy sources to address one of the most pressing environmental challenges of our time.

**Statement of the Problem**

This study aims to develop an innovative eco-bin designed as an eco-friendly Polyethylene terephthalate (PET) bottle compressor powered by solar energy and controlled through Arduino technology.

Specifically, this study seeks to answer the following questions:

1. What are the performance capabilities of the eco-bin in terms of:
2. Durability
3. Compression force; and
4. Cycle time
5. What are the performance capabilities of the eco-bin in terms of efficiency:
   1. Energy consumption; and
   2. Solar power utilization?
6. What are the bottle specifications that affect the efficiency and performance of a pneumatic bottle compressor system in terms of:
   * + - 1. Volume and dimensions of the bottle; and
         2. Thickness of the bottle walls?

**Objectives of the Study**

This study aims to develop an innovative eco-bin designed as an eco-friendly Polyethylene terephthalate (PET) bottle compressor powered by solar energy and controlled through Arduino technology.

Specifically, this study aims to:

* + - 1. Determine the performance capabilities of the eco-bin in terms of:
  1. Durability
  2. Compression force; and
  3. Cycle time
     + 1. Determine the performance capabilities of the eco-bin in terms of efficiency:

a. Energy consumption; and

b. Solar power utilization.

* + - 1. Analyze how the bottle specifications affect the efficiency and performance of a pneumatic bottle compressor system in terms of:
         1. Volume and dimensions of the bottle; and
         2. Thickness of the bottle walls.

**Significance of the Study**

The study of developing an innovative eco-friendly bottle compressor will be beneficial to the following entities:

The direct recipients of this research are the students and staff of Bukidnon National High School. The proposed bottle compressor will benefit the school by promoting proper waste management among its stakeholders. Through the provision of an innovative tool to compress plastic bottles, the school can enhance waste segregation practices, fostering an eco-friendly culture.

To the local community, implementing the bottle compressor is anticipated to have a significant impact on the preservation of environmental sustainability. By facilitating the efficient handling, transport, and recycling of plastic bottles, this innovation minimizes the accumulation of waste in landfills and mitigates contamination in water. Furthermore, this initiative has the potential to serve as a model for adjacent communities, fostering the adoption of similar environmentally sustainable practices and promoting collective efforts toward a cleaner and healthier environment.

For the Department of Environment and Natural Resources (DENR), this study will serve as a bridge that correlates with the vision of the organization. Anchored to the aim of sustaining and taking care of the environment, to promote sustainable environmental practices. The innovative bottle compressor aligns with waste management programs by encouraging recycling and reducing plastic pollution. Additionally, its use of solar energy emphasizes the role of renewable energy in solving environmental issues, reinforcing the DENR's advocacy for sustainable solutions.

To future researchers, this will be a foundation of knowledge that creates a baseline for further innovative research. Future researchers can use this as a blueprint to explore the depths of sagacity to develop a more advanced innovation that seeks to help address global environmental challenges through sustainable engineering practices.

**Scope and Delimitations of the Study**

This study focuses on the development and testing of ECO-BIN, an eco-friendly bottle compressor powered by solar energy and controlled using Arduino technology. It aims to address the issue of plastic bottle waste by reducing volume to improve storage, transport, and recycling. Specifically, the study evaluates the performance of the ECO-BIN in terms of durability, compression force, cycle time, energy consumption, and solar power utilization. Additionally, it analyzes how bottle characteristics; such as volume, dimensions, and wall thickness; affect the efficiency and performance of the pneumatic compression system.

The study is delimited to processing PET (Polyethylene Terephthalate) plastic bottles with a maximum volume of 500ml. Tests will only be conducted under controlled conditions, focusing on the design and functionality of the prototype. The research does not include large-scale production, extended field trials, or testing with other types of plastic materials or larger bottle sizes.

Data collection will include performance measurements such as compression force, energy consumption, and solar power utilization. Statistical methods will be applied to evaluate the results and assess the system’s overall effectiveness. Factors such as material availability, environmental conditions, and technical constraints may influence the outcomes.

**Definition of Terms**

The following terms are theoretically and operationally defined.

***Arduino System***. Arduino is an open-source electronics platform used for creating programmable devices and controlling system operations (Banzi & Shiloh, 2014). The Arduino system in this study controls the pneumatic compressor by managing tasks such as activation, timing, and deactivation. It also monitors system parameters, ensuring efficient operation through real-time adjustments based on sensor feedback.

***Compression Force***. Compression force is a mechanical load that acts inward on a material or structure, leading to a reduction in its volume or inducing deformation by pressing or squeezing its particles closer together (Tekscan, n.d.). In this study, it describes the force generated by the pneumatic compressor to crush PET bottles efficiently.

***Pneumatic Compressor***. A pneumatic compressor is a mechanical device that uses compressed air to perform tasks such as pressing, compacting, or crushing objects (Pawar, 2020). Pneumatic Compressor refers to the primary mechanism responsible for crushing polyethylene terephthalate (PET) bottles into smaller sizes through applied air pressure.

***Durability.*** Durability refers to the ability of a material, component, or system to withstand wear, pressure, or damage over time while maintaining its intended functionality (Campean & Eckert, 2024). Durability in this study refers to the lifespan and resistance of the pneumatic compressor and its components when subjected to repeated compression cycles.

***Cycle Time.*** Cycle time is the total time required to complete one cycle of an operation from the beginning to the end, often measured in seconds or minutes per cycle (Six Sigma, 2024). Cycle time in this study is the time taken by the pneumatic compressor to complete one full compression of a PET bottle, from activation to the full release of pressure.

***Energy Consumption.*** Energy consumption is the amount of energy utilized by a system or device to perform its intended functions over a specific period (Teba, 2024). Energy consumption in this study refers to the total electrical energy required by the Arduino-controlled pneumatic compressor, which is powered by a solar energy system.

***Bottle Specifications.*** Polyethylene Terephthalate (PET) is a type of plastic commonly used for packaging beverages and food items due to its strength, thermo-stability, and transparency (PETRA, 2025). The PET bottles used in this study are plastic beverage containers with a maximum volume of 500 mL, made from polyethylene terephthalate. These bottles serve as the primary material for compression.

**Chapter 2**

**Review of Literature**

This chapter presents the related literature and studies on the Pneumatic PET Bottle Compressor Using Solar Energy And Arduino Control. It further involves relevant studies on the variables being studied. To highlight concepts important to the study, the researchers synthesized relevant literature. The literature and studies mentioned in this chapter address the different ideas, concepts, generalizations, conclusions, and further development related to the study. At the end of each theme, a summary is offered.

**Conceptual Literature**

***Importance of Solar Energy in Waste Management***

Never has this line rung more truly and urgently as in the area of waste management, for few other realities of our times have had us questioning our idea of modern life, as the threat of cities and towns overburdened by waste and bursting at the seams. Solar-powered trash compactor bin has become non-negotiable for bustling urban cities as well as quiet suburban towns, by ushering in a greener, sustainable era in waste management solutions. An innovative waste management solution that come equipped with a solar panel, a battery, compaction machinery, sensors and monitors. They are designed to increase the efficiency of waste management by compacting waste collection, and reducing collection frequency and carbon emissions through solar power (SAB TECH, 2024).

A solar-powered waste compactor is a [smart device](https://en.wikipedia.org/wiki/Smart_device) that reads a [waste bin](https://en.wikipedia.org/wiki/Waste_container)'s fill-level in real-time and triggers an automatic [compaction](https://en.wikipedia.org/wiki/Waste_compaction) of the [waste](https://en.wikipedia.org/wiki/Waste), effectively increasing the bin's capacity by up to 5-8 times (Bigbelly, 2016).

A solar panel is a device that collects and converts solar energy into electricity or heat. It is known as photovoltaic panels used to generate electricity directly from sunlight. Solar thermal energy collection systems are used to generate electricity through a system of mirrors and fluid filled tubes. It is known as energy portal. A solar power technology uses solar cells or solar photovoltaic arrays to convert light from the sun directly into electricity. Photovoltaic is the process in which light energy is converted into electrical power. It is best known as a method for generating solar power by using solar cells packaged in photovoltaic modules, often electrically connected in multiples as solar photovoltaic arrays to convert energy from the sun into electricity (Agaja et al., 2021).

Trash compaction is a process of compacting waste. The various process of trash decomposition produces air pollution and water pollution. In India many garbage dust or waste is left by creating pollution problem as well as environment problem, So we brought up this idea to save the time for compaction dust, recycling and to keep the earth green. Waste management solar power trash compactor use renewable energy to turn public space clean and eco-friendly. Powered by the sun encourages recycling and reduce both greenhouse gas emission and trash collection expenses (Savant et al., 2021)

Using a trash compressor instead of regular trash can increase the amount of trash that can be placed in a trash can of the same size. Even more convenient, the compactor detects when the bin is full and automatically compresses the debris as needed (Lamani et al., 2022).

Studies highlight the effectiveness of solar-powered waste compactors in reducing waste volume, collection frequency, and carbon emissions, making them a sustainable waste management solution (SAB TECH, 2024; Bigbelly, 2016). The integration of solar panels, sensors, and automation enhances waste handling and supports recycling efforts (Agaja et al., 2021; Savant et al., 2021). However, gaps remain in cost accessibility, long-term efficiency, and smart technology integration. Further research is needed to improve durability, automation, and scalability, ensuring broader adoption and greater environmental impact.

***Trash Compactors and Waste Management Solutions***

Trash compactors are mechanical devices designed to reduce the volume of waste, making them applicable in various settings such as domestic, public, and industrial environments. These machines play a crucial role in waste management by compacting trash, thereby enabling larger quantities to be collected at once and improving overall efficiency in waste accumulation systems. By minimizing the space occupied by waste, trash compactors contribute to better handling, transportation, and disposal of recyclable materials. In this context, a Green Trash Compactor has been designed and developed as an innovative semi-automated machine to efficiently reduce the size and volume of recyclable materials such as plastics, paper cups, and PET bottles (Ramli et al., 2024).

Waste segregation presents significant challenges, particularly in distinguishing and managing various forms of waste. Solid waste, in particular, poses a greater challenge due to its higher volume compared to liquid and gaseous waste, necessitating effective volume reduction strategies. To address this issue, mechanical waste compactors play a crucial role in minimizing waste size, facilitating easier handling, transportation, and recycling processes. These machines operate by applying compressive force to materials such as paper, plastic, and aluminum cans, thereby reducing their volume for more efficient waste management. Utilizing a mechanical system composed of components such as mild steel, rack and pinion, wheels, bearings, and shafts, waste compactors function based on rotary motion mechanisms that drive the compaction process. By integrating such technology, waste management systems can enhance their efficiency, reduce space consumption, and optimize recycling efforts (Erebugha et al., 2020).

Traditional trash cans often lead to issues such as overflowing bins, frequent emptying, and inefficient use of space, highlighting the need for a more effective waste management solution. Trash compactors address these concerns through an innovative mechanical design that enables waste compression, significantly reducing its volume and allowing for more efficient storage. With a user-friendly and robust structure, waste compactors are designed for ease of operation and maintenance, making them suitable for various settings, including homes, offices, and public facilities. Extensive testing and validation have demonstrated their effectiveness in optimizing waste storage capacity and improving compaction efficiency across different types of waste materials. By reducing the frequency of waste collection, enhancing space utilization, and promoting responsible waste disposal, the implementation of trash compactors offers a cost-effective and sustainable approach to waste management (Suhaimi et al., 2023).

Effective solid waste management plays a crucial role in protecting public health, preserving the environment, and reducing ecological impacts. One key approach to improving waste management is waste compaction, which significantly reduces waste volume, optimizing storage and transport while minimizing landfill space usage. By compressing waste, compactors enhance efficiency in collection and disposal, lowering transportation costs and reducing greenhouse gas emissions from landfills. Additionally, compacting waste promotes better recycling practices by streamlining waste handling and reducing contamination. Implementing waste compaction strategies contributes to a cleaner, more sustainable environment by improving waste management efficiency and mitigating its environmental footprint (Basavaraju et al., 2025).

Waste compaction plays a vital role in improving storage, transport efficiency, and landfill management. By reducing waste volume, compactors minimize the space required for disposal, enhance cleanliness, and lower the risk of odor and disease. Additionally, compacted waste requires fewer trips for transportation, reducing fuel consumption and operational costs. However, sustainability challenges remain, particularly in ensuring proper waste segregation before compaction and optimizing landfill management for methane extraction. Addressing these issues can enhance the long-term efficiency, cost-effectiveness, and environmental impact of waste management systems (Baidya et al., 2016).

Studies highlight the effectiveness of trash compactors in reducing waste volume, improving storage efficiency, and minimizing collection frequency, making them a crucial waste management solution (Ramli et al., 2024; Suhaimi et al., 2023). The integration of mechanical compression systems, automation, and smart waste monitoring enhances waste handling and promotes sustainable disposal practices (Erebugha et al., 2020; Basavaraju et al., 2025). However, gaps remain in waste segregation efficiency, landfill optimization, and long-term operational costs. Further research is needed to enhance compaction mechanisms, improve automation, and develop cost-effective designs, ensuring broader adoption and greater environmental impact (Baidya et al., 2016).

***Pneumatic Systems in Waste Compression***

Pneumatic systems are essential in various industrial applications, especially waste compaction and automation, due to their efficiency and low maintenance. They use compressed air to deliver consistent force, effectively compacting materials like plastics, metals, and paper, which optimizes waste volume reduction for better storage and transport. Additionally, these systems are crucial in manufacturing automation for tasks like pick-and-place operations and conveyor systems, offering precise control and high speed. Recent advancements include energy-saving mechanisms, such as air recovery systems, which lower operational costs and enhance sustainability, underscoring the growing importance of pneumatic systems in boosting industrial productivity and environmental efficiency (FESCOLO, 2024).

Efficient pneumatic compression devices have demonstrated significant advancements in performance and energy optimization. Modern designs enhance operational efficiency, ensuring improved outcomes in various applications through better management of compression cycles and pressure control, as highlighted in recent studies focusing on the evolution of pneumatic technologies (Kaur et al., 2024).

In addition, the system effectively reduces the volume of waste materials, such as plastic bottles, through an initial crushing process followed by pneumatic compaction. The use of compressed air in the pneumatic compactor allows for uniform force application, optimizing the compaction process while minimizing manual effort (Yadav & Byrappa, 2020).

Pneumatic systems are widely used across various industries because of their versatility and efficiency, going beyond just bottle compression. In manufacturing and assembly lines, devices such as pneumatic presses, pick-and-place robots, and fasteners are commonly utilized for their reliability and speed. These tools are particularly suited for mass production, as they can perform repetitive tasks with minimal errors. For example, pneumatic presses utilize air pressure to exert force during processes like shaping, stamping, or assembling parts. Additionally, pick-and-place robots equipped with pneumatic grippers can handle items quickly and effectively (Bello et al., 2020).

The integration of pneumatic systems in industrial applications significantly enhances productivity, operational efficiency, and safety. It offers improved precision, reduced manual effort, and faster processing times compared to traditional methods. The pneumatic systems not only optimize industrial processes, such as bottle compression but also contribute to sustainable and cost-effective operations (Gautam et al., 2024).

Pneumatic systems are effective in industrial applications for waste compaction and automation, offering efficiency, low maintenance, and consistent force, which enhance waste volume reduction and productivity (FESCOLO, 2024; Yadav & Byrappa, 2020). Innovations in energy-saving mechanisms and pressure control have improved sustainability and cut operational costs (Kaur et al., 2024; Gautam et al., 2024). These systems also enhance manufacturing productivity through reliable operations, such as pneumatic presses and pick-and-place robots (Bello et al., 2020). However, further research is needed to address gaps in renewable energy use and cost efficiency, particularly in developing solar-powered pneumatic mechanisms controlled by Arduino for better energy efficiency and scalability in waste management.

***Polyethylene Terephthalate (PET) Recycling***

Polyethylene Terephthalate (PET) is a widely used thermoplastic polymer due to its excellent mechanical and chemical properties. It is lightweight, strong, impact-resistant, and has high thermal stability, making it ideal for various applications, particularly in the packaging, textile, and automotive industries. PET’s low gas permeability and resistance to moisture enhance its suitability for food and beverage containers, contributing to its extensive industrial usage (Papageorgiou et al., 2021).

PET waste poses significant environmental concerns. Since PET is non-biodegradable, it accumulates in landfills and marine ecosystems, leading to long-term pollution. Improper disposal methods such as incineration release toxic chemicals, including carbon monoxide and dioxins, exacerbating air pollution. Furthermore, ineffective waste management infrastructure in many regions contributes to low recycling rates, intensifying the environmental impact of PET waste (Brahimi et al., 2020).

Recycling PET reduces carbon emissions and energy consumption compared to primary plastic production. Mechanical and chemical recycling processes enable the conversion of used PET into reusable materials, decreasing the demand for virgin PET production and promoting a circular economy (Garcia & Robertson, 2022).

An efficient PET recycling system fosters sustainable manufacturing and reduces reliance on fossil fuels. Recycling PET not only decreases plastic waste but also mitigates the environmental footprint associated with raw material extraction and processing (Kumar & Singh, 2023).

Advancing recycling technologies and infrastructure is essential for sustainable waste management. By implementing effective PET recycling strategies, industries and communities can significantly reduce pollution and contribute to a more sustainable environment (Huang et al., 2021).

Studies emphasize PET’s widespread industrial use due to its mechanical strength, thermal stability, and resistance to moisture, making it ideal for packaging, textiles, and automotive applications (Papageorgiou et al., 2021). However, PET waste accumulation poses severe environmental risks due to its non-biodegradability and improper disposal, contributing to landfill overflow and air pollution (Brahimi et al., 2020). While mechanical and chemical recycling promote a circular economy by reducing carbon emissions and fossil fuel dependence, inefficiencies in waste management infrastructure hinder widespread adoption (Garcia & Robertson, 2022; Kumar & Singh, 2023). Further research is needed to enhance recycling technologies, improve waste collection systems, and increase PET recovery rates for a more sustainable waste management approach (Huang et al., 2021).

***Arduino Technology in Automation***

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It consists of microcontroller boards that can read inputs, such as light on a sensor, a finger on a button, or a Twitter message, and turn them into outputs, like activating a motor, turning on an LED, or publishing something online. Users can program the board to perform specific tasks by sending a set of instructions to the microcontroller. This flexibility makes Arduino a popular choice for various automation applications (Zlatanov, 2016).

In industrial automation, Arduino has been utilized for prototyping, embedded systems, and as a cost-effective alternative to traditional Programmable Logic Controllers (PLCs). Its ability to interface with a wide range of sensors and actuators allows for the development of custom automation solutions tailored to specific industrial needs. For instance, Arduino has been employed to control machinery, monitor production lines, and manage energy consumption, thereby enhancing efficiency, accuracy, and productivity in industrial settings (Armenta, 2022).

The integration of Arduino technology into waste management systems has led to the development of smart solutions aimed at optimizing waste collection, segregation, and disposal processes. One notable application is the creation of smart waste bins equipped with sensors and Arduino microcontrollers. These bins can monitor waste levels in real-time and notify waste management personnel when they are full, ensuring timely collection and preventing overflow (Vijay et al., 2019).

Additionally, Arduino-based systems have been designed to segregate waste automatically. By utilizing various sensors, such as inductive proximity sensors for metal detection and moisture sensors for identifying wet waste, these systems can sort waste into categories like metal, wet, and dry. The sorted waste is then directed into respective bins through mechanical actuators controlled by the Arduino. This automated segregation not only reduces manual labor but also enhances the efficiency of recycling processes (Iyer, 2018).

Furthermore, the Internet of Things (IoT) has been integrated with Arduino to develop comprehensive waste management solutions. For instance, an IoT-based smart waste management system using Arduino involves placing sensors in dumpsters to monitor fill levels continuously. When a dumpster reaches its capacity, the system sends alerts to waste collection services, enabling them to plan efficient collection routes and schedules. This approach minimizes unnecessary trips, reduces fuel consumption, and lowers operational costs, contributing to environmental sustainability (Srivastava, 2024).

The versatility of Arduino as an open-source electronics platform has paved the way for significant advancements in automation, particularly in industrial and waste management applications. It powers smart bins that monitor waste levels for timely collection (Vijay et al., 2019) and automated segregation systems that enhance recycling efficiency (Iyer, 2018). Integrated with IoT, Arduino allows real-time waste monitoring and optimized collection schedules, reducing costs and promoting sustainability (Srivastava, 2024). These innovations highlight its role in modernizing waste management through automation and efficiency.

**Related Studies**

***Use of Polyethylene terephthalate (PET)***

Joseph et al. (2024) examine various techniques involved in the recycling of polyethylene terephthalate (PET) due to its extensive use and the resulting global waste crisis. The study discusses conventional recycling methods, focusing on the influence of diverse depolymerization reaction variables, along with the advantages and disadvantages of each technique. The review highlights major advancements in plastic waste recycling technologies, emphasizing the bio-recycling of PET as a sustainable and economical solution within the circular economy. The findings suggest that while polymer waste reuse is costly due to contamination and sorting challenges, PET recycling can be beneficial when integrated into the production of concrete products and wood-polymer boards, reducing environmental impact and promoting sustainable waste management.

Furthermore, Albatayneh and Akhtar (2024) evaluate the potential of recycled polyethylene terephthalate (PET) as an alternative material in the construction sector to enhance sustainability. The study systematically reviews existing research on PET's application in concrete, particularly as a substitute for natural sand at ratios of 5% to 20% and as a cement additive at 0.5% to 2% by weight. The results reveal that up to a 10% PET replacement improves compressive strength, while higher replacement levels lead to strength reduction. Additionally, incorporating PET as a 1% cement additive optimizes flexural strength, reinforcing its structural viability. The findings highlight PET's potential to mitigate environmental pollution and promote eco-friendly construction materials while emphasizing the need for further research to refine its application.

Moreover, Soong et al. (2022) review recent advances in the biological recycling of polyethylene terephthalate (PET) plastic waste, emphasizing enzymatic degradation as a sustainable alternative to traditional recycling methods. The study highlights PET hydrolases, including cutinases, lipases, and esterases, which break down PET into monomers like terephthalic acid (TPA) and ethylene glycol (EG). Results indicate that enzyme efficiency depends on factors such as PET crystallinity, temperature, and enzyme engineering. Compared to mechanical and chemical recycling, biorecycling offers an eco-friendly approach with minimal environmental impact. The study concludes that optimizing enzyme stability and activity could enhance PET biodegradation, supporting a circular economy for plastics.

Thus, Thachnatharen et al. (2021) review the current techniques for managing polyethylene terephthalate (PET) plastic waste, emphasizing the need for effective recycling due to its increasing environmental impact. The study discusses chemical and mechanical recycling methods, including depolymerization techniques such as methanolysis, hydrolysis, glycolysis, aminolysis, and ammonolysis. Mechanical recycling steps like plastic collection, sorting, chipping, washing, and pelleting are also examined. The results indicate that chemical recycling can achieve high-purity PET recovery, while mechanical recycling remains a widely used and cost-effective method despite challenges in contamination and sorting. Additionally, the study explores degradation methods such as biodegradation and photocatalytic degradation, highlighting their potential but noting that photocatalytic degradation is still under research. The findings emphasize the necessity of collaborative efforts among the public, government, and private sectors to improve PET waste management and reduce environmental pollution.

In addition, Husnah et al. (2021) tested the effect of polyethylene terephthalate (PET) plastic as a partial and full replacement for coarse aggregate in lightweight concrete. The study evaluates different PET replacement levels (0%, 40%, 50%, 70%, and 100%) and their impact on compressive strength and density over 14 and 28 days. The highest compressive strength is observed at 40% PET replacement, reaching 250 kg/cm² at 14 days and 205 kg/cm² at 28 days. Beyond this level, strength declines, making higher PET variations more suitable for non-structural applications. The study confirms that PET significantly reduces concrete weight, with a 100% PET mixture meeting the lightweight concrete classification. The findings suggest PET can enhance sustainability in construction by reducing plastic waste while maintaining performance. A 40% PET substitution provides an optimal balance between strength and weight reduction, while full PET replacement is beneficial for lightweight, non-structural applications. Further research is recommended to optimize PET-based concrete's mechanical properties and long-term durability.

The reviewed studies highlight the widespread application of polyethylene terephthalate (PET) recycling in waste management, construction, and biological degradation. Research emphasizes chemical, mechanical, and enzymatic recycling methods, with biorecycling emerging as a sustainable alternative (Soong et al., 2022; Thachnatharen et al., 2021). Studies also explore PET’s role in construction, demonstrating its effectiveness as a partial substitute for sand and coarse aggregates, improving compressive and flexural strength at optimal replacement levels (Albatayneh & Akhtar, 2024; Husnah et al., 2021). However, challenges persist, including contamination, sorting inefficiencies, and limited large-scale implementation (Joseph et al., 2024). Additionally, while biodegradation and photocatalytic recycling show promise, they require further optimization and scalability. Addressing these gaps will enhance PET recycling efficiency, structural applications, and sustainability in waste management.

***Use of Solar-Powered Waste Management Innovations***

A study by Lakhotia et al. (2021) developed a solar-powered trash compactor that increases bin capacity by 5–8 times daily, integrating a solar PV source with battery storage to ensure reliability. In this paper, a maximum power point tracking (MPPT)-based charging topology is used to transfer the maximum power from the solar PV to the battery and thus to enhance the power conversion efficiency of the power electronic interface. The system employs MPPT-based charging for efficient power conversion and features grid integration to maintain operation during prolonged monsoons while exporting surplus energy. Similarly, the researcher's eco-bin utilizes solar energy to power a pneumatic compressor for efficient waste compression, aligning with the sustainable approach of solar-integrated trash compactors.

Similarly in this study, Ramli et al. (2025) designed and developed a Green Trash Compactor as a semi-automated machine powered by solar energy as a back up generator to efficiently reduce the size and volume of recyclable materials such as plastics, paper cups, and PET bottles. This innovation enhances waste management by compacting trash, allowing for more efficient collection and disposal. The study focused on optimizing the sensor layout to minimize the impact during the compaction process, reducing the need for heavy load cells or weight sensors. The system operates through button-activated input commands, where load cells detect force, and a microcontroller processes the data to execute compaction. The results demonstrated that the Green Trash Compactor effectively reduced waste volume, contributing to lower transportation costs and improved waste management efficiency. This research aligns with the present study, which integrates solar energy and Arduino-based automation to develop an eco-friendly trash compactor, further enhancing sustainability in waste management systems.

Furthermore, the study of Tamakloe & Rosca (2020), developed a solar-powered, self-compacting smart bin integrated with IoT for efficient waste management. The prototype monitors internal rubbish levels, compacts waste to free approximately 25% of space per cycle, and tracks total weight, transmitting data to a secure server-side application. Additionally, a web-based system optimizes waste collection routes for improved city waste management. This aligns with the current study as it also aims to automate the traditional trash bin compressors with IoT-based coding on an Arduino module powered by solar energy.

Moreover, the study of Ajibola and Ogbolumani (2024) discussed the escalating global waste crisis, with over 33% of 2.01 billion tons of annual waste being mismanaged and projections reaching 3.40 billion tons by 2050. Their study explored the integration of IoT-powered solar waste management systems with smart battery storage to ensure continuous operation, reduce reliance on grid power, and minimize carbon emissions. A prototype system incorporating IoT sensors, solar panels, and smart battery storage was designed and simulated to optimize waste collection efficiency. This prototype fits the compressing eco-bin of this research since it uses solar energy to run a pneumatic compressor, therefore reducing sustainable waste by effective compression technology.

Additionally, the study of Hesham et al. (2023), defined smart bins as a new type of garbage bin that can be used to sort and categorize garbage in a variety of ways. The researchers developed a Solar-Powered Smart Bin that revolutionizes waste classification for sustainable waste management. It explores the concept of smart garbage systems, distinguishing them from traditional waste disposal methods by evaluating a combined garbage sorting and real-time monitoring system. This promotes the development of solar-powered waste reduction technology as their study investigated the advantages and disadvantages of these technologies as it highlights the importance of innovative solutions whilst maintaining sustainability. It corresponds with the current study, as it not only advocates but also incorporates solar energy as a sustainable power source for these compressors, providing a feasible option and an efficient alternative.

The reviewed studies share similarities with the present research, yet key differences in their integration, objectives, and technological approaches set them apart. Lakhotia et al. (2021) developed a solar-powered trash compactor that significantly increased bin capacity through MPPT-based charging for efficient power conversion; however, their focus was primarily on energy optimization rather than automation in waste compression. Likewise, Ramli et al. (2025) designed a semi-automated Green Trash Compactor powered by solar energy, but it operated through button-activated commands rather than incorporating IoT-based automation for enhanced functionality. Tamakloe & Rosca (2020) introduced a smart bin with IoT capabilities to monitor waste levels and optimize collection routes, yet their system lacked pneumatic compression, a key feature of the present study to improve compaction efficiency. Ajibola and Ogbolumani (2024) tackled the global waste crisis by developing an IoT-powered solar waste management system with smart battery storage, aligning with this research’s sustainability goals but without integrating pneumatic technology for waste reduction. Lastly, Hesham et al. (2023) explored solar-powered smart bins for waste classification, but their study focused more on sorting mechanisms rather than compression, a critical aspect of the Pneumatic PET Bottle Compressor Using Solar Energy and Arduino Control.

***Use of Arduino-Based in Waste Management Systems***

The integration of Arduino technology into waste management has led to innovative solutions aimed at automating waste segregation and enhancing efficiency. Tan et al. (2024) developed an automated waste segregation system utilizing the Arduino Uno R3 microcontroller. This system employs various sensors to identify and sort different types of waste, improving the accuracy and speed of waste separation processes. The study suggests that such Arduino-based systems can significantly contribute to more sustainable and environmentally friendly waste management practices.

In another study, Chowdhury et al. (2024) introduced a smart bin system that combines Arduino control with deep learning algorithms for real-time waste classification. The system utilizes a camera to capture images of disposed items, which are then processed using a convolutional neural network to accurately categorize waste. This approach not only automates the sorting process but also enhances the precision of waste classification, leading to more efficient recycling efforts.

Similarly, an automatic waste segregation and monitoring system was designed by Sharma et al. (2024), incorporating Arduino technology to facilitate the sorting of waste into biodegradable and non-biodegradable categories. The system uses sensors to detect material types and directs waste accordingly, thereby reducing manual labor and the potential for human error in the segregation process. This innovation underscores the role of Arduino in streamlining waste management operations.

Additionally, an IoT-integrated deep learning model combined with a smart bin system was proposed by Saravanan et al. (2023). This system employs Arduino microcontrollers alongside IoT sensors to monitor waste levels and classify waste types in real-time. The integration of deep learning allows for continuous improvement in classification accuracy, while the IoT capabilities enable efficient communication with waste management services for timely collection and processing.

In a study by Endaya et al. (2020), an automated waste segregator with smart compression was designed and implemented using an Arduino Uno microcontroller. The system employs a stepper motor for bin rotation and a linear actuator for compressing paper and plastic waste. A push button controls the bin rotation, facilitating efficient waste segregation and compression. This approach aims to enhance waste management efficiency by automating the sorting and compression processes.

Arduino technology has revolutionized waste management by enabling automated segregation, smart classification, and efficient monitoring. Studies have demonstrated its effectiveness in improving sorting accuracy through sensors (Tan et al., 2024), deep learning integration (Chowdhury et al., 2024), and IoT connectivity (Saravanan et al., 2023). Additionally, automated systems reduce human error and labor in waste sorting (Sharma et al., 2024), while innovations like smart compression further optimize waste processing (Endaya et al., 2020). These advancements highlight Arduino’s critical role in promoting efficiency and sustainability in modern waste management.

***Use of Trash Compactors and Waste Volume Reduction***

Nafiz et al. (2023) introduced "ConvoWaste," an automatic waste segregation machine utilizing deep learning and image processing techniques. Their system employs a deep convolutional neural network (DCNN) to classify waste accurately and uses a servo motor-based mechanism to sort detected waste into corresponding bins. The machine also features real-time monitoring and notifications through ultrasonic sensors and GSM-based communication technology. This study is pertinent to the current research as it demonstrates the integration of automation and smart technologies in waste management, aligning with the use of Arduino control in the Pneumatic PET Bottle Compressor.

Sigongan et al. (2023) developed "GULP," a solar-powered smart garbage segregation bin equipped with machine learning image processing and SMS notification capabilities. The system segregates solid waste into respective bins and notifies utility staff when the bins need to be emptied. It operates independently using solar energy, promoting environmental sustainability. This research is relevant to the current study as it combines solar power and automation in waste management, similar to the integration of solar energy and Arduino control in the Pneumatic PET Bottle Compressor.

Bassey et al. (2024) designed and developed a dual-powered air compressor for tire inflation, incorporating both AC and solar power sources. An Arduino controller was used to allow for automatic operations of the system. The test results showed satisfactory performance, with the machine delivering 20 liters of air at 40 psi within 255 seconds. This study is relevant to the current research as it demonstrates the feasibility of using solar energy and Arduino control in pneumatic systems, which are key components in the Pneumatic PET Bottle Compressor.

Pawar et al. (2024) examined the application of the Internet of Things (IoT) in waste management systems, proposing a data-driven approach for optimizing waste collection and disposal. Their study highlights how smart technologies, such as sensor-based monitoring and automated control, contribute to a more efficient and sustainable waste management process. This research is relevant to the current study as it underscores the importance of integrating smart technologies, such as Arduino-controlled automation, into waste management solutions. The Pneumatic PET Bottle Compressor aligns with this trend by utilizing sensor-based mechanisms to optimize the compression of plastic bottles.

Kumar et al. (2023) conducted a review on artificial intelligence (AI) applications in waste management, particularly in smart cities. Their study discusses the implementation of AI-powered waste-sorting robots and smart bins to improve waste segregation and processing efficiency. While the present study does not incorporate AI, it aligns with the broader theme of utilizing advanced technologies to enhance waste management practices. The integration of solar energy and Arduino automation in the current study reflects a similar approach, aiming to create an intelligent and sustainable solution for plastic waste compression.

The reviewed studies emphasize the increasing role of automation, smart technologies, and sustainable energy sources in modern waste management. From deep learning-based waste segregation (Nafiz et al., 2023) to solar-powered smart bins (Sigongan et al., 2023) and dual-powered pneumatic systems (Bassey et al., 2024), these advancements demonstrate significant progress in optimizing waste collection and processing. Additionally, IoT applications (Pawar et al., 2024) and AI-driven solutions (Kumar et al., 2023) highlight the potential of intelligent waste management systems in enhancing efficiency and sustainability. However, while these studies contribute to the field, none specifically focus on compressing PET bottles using a pneumatic mechanism powered by solar energy and controlled by Arduino. This gap underscores the significance of the present research, which aims to integrate these technologies into a compact and efficient system that addresses the growing issue of plastic waste.

***Use of Pneumatic Compression Technology***

A study by Yadav and Byrappa (2020) developed an automated waste management system that integrates a crusher with a pneumatic compactor. This innovative approach aims to enhance the efficiency of waste volume reduction. It highlights the significant advantages of pneumatic systems over traditional mechanical compactors, emphasizing energy efficiency, reduced operational costs, and simplified maintenance. The pneumatic compactor enhanced performance through faster cycle times and consistent compaction results. It is a suitable solution for urban waste management where space optimization and operational efficiency are critical.

Farre et al. (2023) conducted a comprehensive review of pneumatic urban waste collection systems, positioning them as sustainable alternatives to conventional truck-based waste collection methods. The environmental benefits of pneumatic systems are reduced greenhouse gas emissions, minimized traffic congestion, and improved urban hygiene. In case studies from various urban settings, the authors demonstrated that pneumatic waste collection systems can significantly enhance waste management efficiency, particularly in densely populated areas. The study concludes that integrating pneumatic systems into municipal waste management strategies can support sustainability goals and reduce the environmental footprint of waste collection activities.

Furthermore, the study of Venkatesh & Jagadeesha (2022) explores the utilization of Pneumatic Underground Collection (PUC) technology as an advanced waste management solution for smart and sustainable cities. The research focuses on how PUC systems use vacuum pressure to transport waste through underground pipelines, eliminating the need for traditional waste collection vehicles. This system significantly reduces environmental impacts such as air and noise pollution while improving waste handling efficiency in urban areas. The study emphasizes the ability of operational mechanisms of PUC systems to streamline waste collection processes, minimize labor requirements, and enhance urban cleanliness. It also discusses the challenges related to the high initial expenses associated with installation and the need for specialized maintenance. However, the study concludes that PUC technology is a viable and eco-friendly waste management approach, especially when integrated into urban planning and supported by effective policy frameworks.

Moreover, López et al. (2023) developed an innovative decision matrix to guide the integration of Pneumatic Urban Solid Waste Collection Systems (PUSWCS) into smart city projects. The study comprehensively analyzed the advantages and disadvantages of pneumatic collection systems from technical, economic, and social perspectives. The proposed decision-making tool addresses the complexities of evaluating the feasibility and desirability of incorporating PUSWCS in municipalities or specific areas, aligning the assessment with the United Nations’ Sustainable Development Goals. This approach provides a structured framework for policymakers and urban planners to make informed decisions regarding the implementation of pneumatic waste collection technology.

Conducted in the Philippines, Endaya et al. (2021) utilize pneumatic components to automate the waste compaction process, applying consistent and controlled force to reduce the volume of waste materials. The pneumatic mechanism operates through compressed air, which drives the compaction unit to exert uniform pressure, ensuring efficient space utilization within the bin.

The reviewed studies highlight the growing role of pneumatic systems in modern waste management, emphasizing efficiency, sustainability, and adaptability in urban settings. From automated compactors (Yadav & Byrappa, 2020) and underground collection systems (Venkatesh & Jagadeesha, 2022) to decision-making tools for smart cities (López et al., 2023) and localized applications in the Philippines (Endaya et al., 2021), these advancements demonstrate improved waste reduction and operational efficiency. However, none specifically focus on compressing PET bottles using a solar-powered pneumatic mechanism controlled by Arduino, highlighting the relevance of the present research in addressing plastic waste through an integrated, energy-efficient system.

**Chapter 3**

**Methodology**

This chapter discusses the methods and procedures in the conduct of the study. It features the research design, research locale, collection and preparation of data, data gathering procedure, data analysis, procedural framework, flowchart, and photo documentation that will be used to analyze the data.

**Research Design**

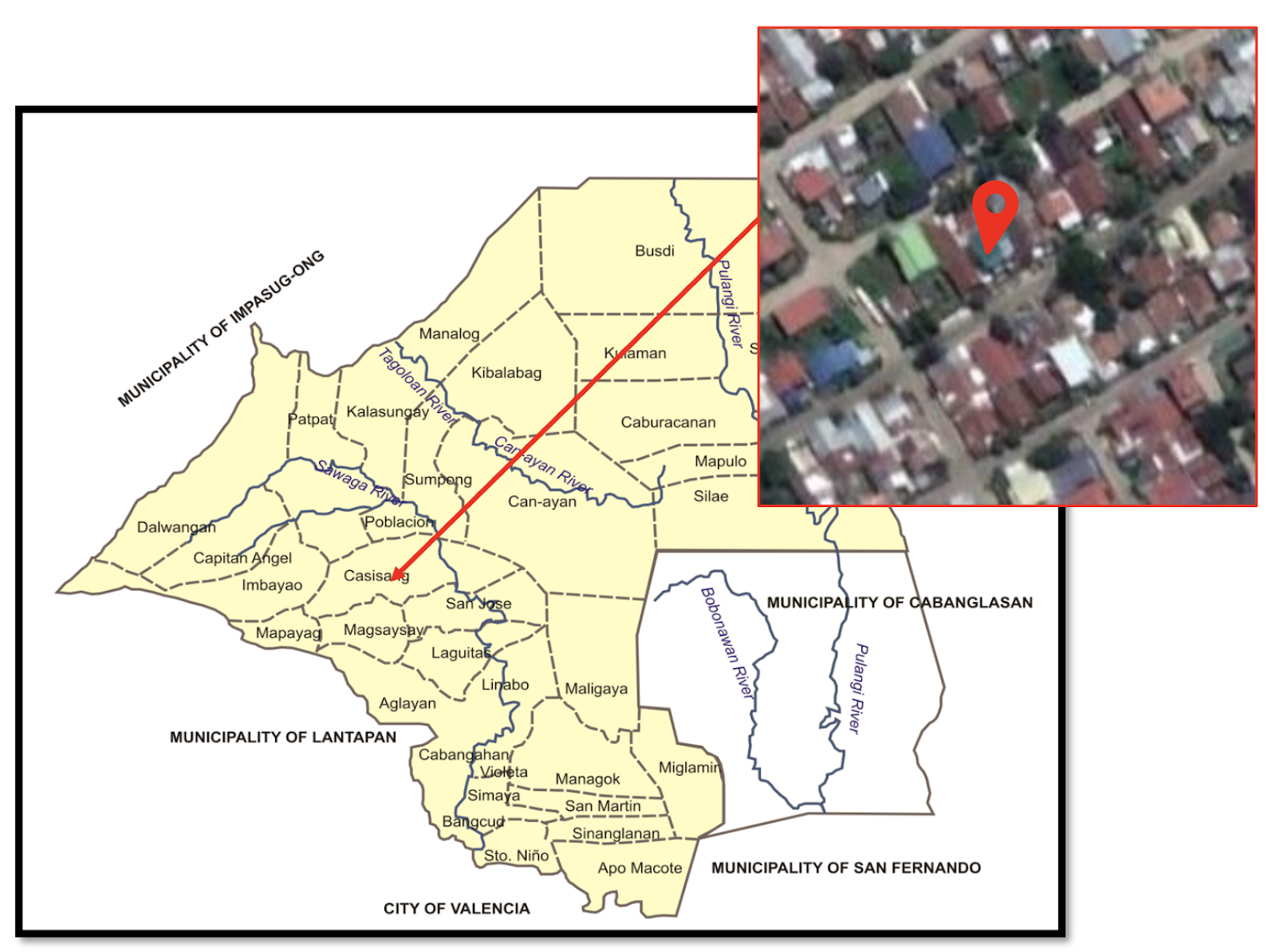
In this research, the experimental research design will be utilized to test the development of the eco-friendly Polyethylene terephthalate (PET) bottle compressor, also known as the eco-bin, powered by solar energy and controlled through Arduino technology. Testing and data collection will evaluate the eco-bin's performance and efficiency, specifically its durability, compression force, cycle time, energy consumption, and solar power usage. The primary objective of experimental research is to establish cause-and-effect relationships by manipulating one or more independent variables and observing the resulting changes in the dependent variables (Em, 2024).

The experimental research design is suitable for this study as it aims to evaluate the effectiveness of integrating pneumatic technology with renewable energy sources and automated control systems in compressing PET bottles efficiently. This approach allows for controlled testing of different system configurations, providing comprehensive data on performance metrics under varying conditions, thereby ensuring the reliability and validity of the research findings.

**Research Locale**

This study will be conducted at Block 2 Lot 11 Paglaum Phase 1 Casisang, Malaybalay City Bukidnon, situated at approximately 8.14106, 125.12088, and elevated 622 meters (2,041 feet) above sea level. Nestled in the scenic region of Bukidnon, the site offers a naturally windy atmosphere that is enhanced by the presence of a three-story building with the elevation of 13 meters (42.7 Feet), providing an elevated platform for wind capture. This site was selected due to its accessibility to necessary materials, availability of adequate workspace, and stable environmental conditions essential for testing the solar-powered system and Arduino control mechanisms. The location allowed efficient integration of the pneumatic compression system, solar panel setup, and electronic components. The materials, including PET bottles, pneumatic components, solar panels, and Arduino controllers, were gathered based on availability, ensuring consistency in testing and evaluation.

**Figure 1.**

***Sampling site of the study***

**Collection and Preparation of Data**

The data collection for this study follows a systematic approach to ensure accurate assessment of the Pneumatic PET Bottle Compressor. The procedure includes performance testing, energy efficiency evaluation, and response time measurement. The collected data will serve as the basis for analyzing the system’s effectiveness, reliability, and sustainability.

#### ***Compression Efficiency Measurement***

To assess the efficiency of the PET bottle compressor, compression trials are conducted under controlled conditions. PET bottles of uniform size and volume are placed in the system, and the percentage reduction in volume is recorded for each trial. The initial and final dimensions of the bottles are measured using digital calipers to ensure precision. Multiple trials are performed to obtain reliable data, and results are averaged to determine overall efficiency.

#### ***Energy Consumption Analysis***

The energy consumption of the compressor is analyzed by measuring the power usage of the pneumatic system and its solar energy dependency. A digital wattmeter is used to monitor power intake from the solar panels and battery storage. The system's voltage and current readings are logged during operation to compute total energy consumption. These measurements help evaluate the feasibility of the solar power integration and its impact on system sustainability.

#### ***Response Time Evaluation***

The response time of the pneumatic system is tested by measuring the time taken for the compressor to complete a single compression cycle. A high-speed digital timer records the duration from bottle insertion to full compression. The test is repeated multiple times to account for variations in system performance. The mean response time is calculated to determine consistency and efficiency.

### **Data Preparation**

The collected data is systematically tabulated to facilitate analysis. Measurements from compression efficiency, energy consumption, and response time are recorded in structured spreadsheets for easier interpretation. Each test trial is documented, ensuring that all variations in system operation are accounted for.

To ensure data accuracy and reliability, calibration of measuring instruments is performed before each test. Instruments such as digital calipers, wattmeters, and timers are checked for precision and consistency. Additionally, trials are conducted multiple times under identical conditions to eliminate potential errors and obtain reproducible results.

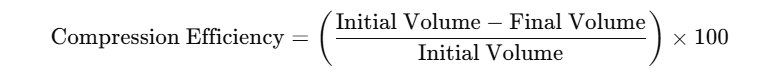
Since the study involves mechanical and electrical components, all procedures are conducted following safety protocols to prevent potential hazards. The sustainability impact of the project is also considered by ensuring that materials used are environmentally friendly, aligning with the study's goal of promoting eco-friendly waste management solutions.

By following these data collection and preparation methodologies, the study ensures that the findings are accurate, reproducible, and scientifically valid. The results obtained will provide valuable insights into the efficiency, energy optimization, and feasibility of the Pneumatic PET Bottle Compressor as a sustainable waste management innovation.

**Data gathering Procedure**

The parameters measured and collected during the experiment include the compression efficiency, energy consumption, compression time, and the volume reduction ratio of PET bottles. The compression efficiency and volume reduction ratio were determined by measuring the initial and final volume of the PET bottles before and after compression. Energy consumption was monitored by measuring the power drawn by the solar-powered system during operation. Compression time was recorded using a timer to determine the duration required for each compression cycle.

The following formulas will be used:

1. **Compression Efficiency (%)** – calculated using the formula: 
2. **Energy Consumption (Wh)** – computed by: 
3. **Compression Time (s)** – measured directly using a stopwatch for each compression cycle.

Through the collection of this data, the researchers obtained the necessary insights to evaluate the effectiveness of the pneumatic PET bottle compressor using solar energy and Arduino control.

**Data Analysis**

To interpret and analyze the data gathered throughout the study, the researchers employed descriptive statistics to assess the performance of the Pneumatic PET Bottle Compressor Using Solar Energy and Arduino Control. Specifically, data related to compression force, cycle time, energy consumption, and solar power utilization were analyzed using measures of central tendency, notably the mean or average, to determine overall system efficiency. Additionally, the data were further evaluated using measures of variability, specifically standard deviation, to assess the consistency and reliability of the system's performance under varying conditions. This approach enabled the researchers to examine the impact of bottle specifications, such as volume and wall thickness, on compression efficiency and system effectiveness.

**Procedural Framework**

The development of the Pneumatic PET Bottle Compressor follows a systematic process to ensure efficiency, functionality, and reliability. The procedure begins with the planning and designing phase, where the overall concept, system layout, and operational mechanisms are established. This step involves creating a schematic diagram to illustrate the interconnection of components, including the pneumatic system, solar power integration, and Arduino-based automation. The design process ensures that the compressor effectively reduces the volume of PET bottles while optimizing power consumption.

Following the design phase, the gathering of materials and tools is conducted. Essential components such as the pneumatic cylinders, sensors, solar panels, Arduino microcontroller, and structural materials are procured based on the design specifications. Proper selection of materials is crucial to achieving durability, efficiency, and cost-effectiveness in the final system.

The construction phase involves assembling the PET bottle compressor according to the schematic diagram. This includes fabricating the structural frame, integrating the pneumatic system for compression, and installing the Arduino-based control system for automation. Throughout the construction, photo documentation is performed to track progress and ensure adherence to design specifications. Any modifications or adjustments needed to improve the system’s performance are addressed during this stage.

After construction, the integration of solar power and Arduino control is implemented. The system is configured to utilize solar energy as the primary power source, ensuring sustainability and reducing dependency on conventional electricity. The Arduino microcontroller is programmed to regulate the compression process, enhancing automation and efficiency. This integration optimizes energy consumption and enables real-time control of the compression mechanism.

The testing and performance evaluation phase is conducted to assess the compressor’s effectiveness in reducing PET bottle volume. Key performance indicators include compression efficiency, energy consumption, and response time of the pneumatic system. Trials are performed under various operating conditions to validate the system’s reliability and performance.

In the data analysis stage, the collected performance data is statistically processed. The mean and standard deviation of compression efficiency, energy consumption, and response time are calculated to determine the system’s consistency and reliability. These statistical measures provide insights into the system’s performance stability and help identify areas for improvement.

Finally, in the results and discussion phase, the findings from the data analysis are interpreted to evaluate the feasibility of the developed PET bottle compressor. Comparisons are made with existing waste management solutions, and potential enhancements are suggested. The results provide a basis for further optimizations, ensuring that the system can be effectively implemented as a sustainable and automated waste management solution.

**Flowchart of the Study**

Planning and Designing of PET Bottle Compressor

Schematic Diagram

Gathering of Materials and Tools

Construction of the PET Bottle Compressor

Photo Documentation

Integration of Solar Power and Arduino Control

Testing and Performance Evaluation

Compression Efficiency

Energy Consumption

Response Time

Data Analysis

Results and Discussion

Mean

Standard Deviation

**Photo Documentation**

For the documentation, the researchers will use an iPhone 15 Pro with a 48-megapixel sensor and 12-megapixel resolution to document the preparation, progress, and analysis of the study. The documentation will serve as evidence that the experiment was essentially executed and to support research findings, observation, and interpretations