EGB101

Engineering Design and Professional Practice

Assessment 3A: Professional Report

Group 4Q

Author Declaration

The authors declare that they have read the contents of this report and agree to its publication in its current form. They confirm that they have contributed to the preparation, review, and/or writing of this document and collectively take responsibility for its contents.

By signing below, each author acknowledges their role in this work and affirms their agreement with the inclusion of their name as a contributing author.

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STATEMENT OF CONTRIBUTIONS

A statement of contributions must be included as part of the report. This needs to indicate what section of the report each team member wrote. It also needs to indicate what technical component(s) of the report each group member worked on. Technical components are: Structural Design, Mechanical Design and Electrical Design. Group marks can be modified for individuals with insufficient contributions given that evidence is provided (documentation, project work in the Microsoft Teams environment, and meetings with project managers and tutors).

TABLE 2. STATEMENT OF GROUP CONTRIBUTIONS

Team Member	Report Sections Written	Technical Contributions
Krystian Rozanski	- Executive summary - Section 1 - Section 3 - Section 4 - Section 5	- Structural, Mechanical, and Electrical design
Matthew Amos	Project sustainability	
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Daniel Suter	5.2 Prototype demonstration	Additional research, analysing the prototype's performance and technical sketches
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EXECUTIVE SUMMARY

This report presents the development of WALI (Waste Awareness and Lifecycle Innovation)—a sustainable, low-energy, automated waste sorting system designed to separate paper, cardboard, and metal using passive and active separation methods. The project was commissioned by Brisbane City Council as part of its sustainability initiative and aligns with United Nations Sustainable Development Goals 7, 11, 12, and 13.

The final design incorporates an inclined plane, a fan for aerodynamic paper separation, and a neodymium magnet for ferrous metal extraction. All materials used were selected for their environmental impact, durability, and recyclability—including aluminium, HDPE, and ethically sourced natural rubber. Detailed testing confirmed system functionality within key constraints: <20 seconds processing time, <1.5 kg mass, no pre-stored energy, and no damage to waste materials.

The system operates through a gravity-fed slope, where lightweight paper is deflected by airflow, metal is magnetically captured, and heavier cardboard proceeds to the end of the sorting path. The fan's airflow (9.87 m/s) and magnet's attraction radius (30 mm) were determined and verified through applied engineering analysis and practical trials. Structural integrity was confirmed through load testing, and the minimal electrical system was validated for energy efficiency.

Deployed in Eagle Farm—a high-waste industrial zone in Brisbane—the prototype integrates seamlessly into existing waste streams. Its design promotes community and environmental benefits by improving recycling rates, reducing landfill burden, and minimising emissions. Lifecycle sustainability and wider impact considerations were embedded throughout the design process.

Team collaboration was evident through iterative design refinement, resolution of technical trade-offs, and strong project planning. The result is a practical, scalable solution ready for real-world application that meets environmental, social, and technical criteria.

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1 INTRODUCTION

1.1 PROJECT CONTEXT AND SCOPE

Waste management and segregation have played a vital role in preventing diseases and mitigating climate change effects. Inappropriate disposal or processing of this waste can lead to significant sustainability issues impacting the lives of current and future society, through rapid spreading of diseases, pollution and depletion of the ozone layer (Abubakar et al., 2022). In recent times, 10% of recycling is done in an inappropriate manner within the Greater Brisbane area, and many countries yield an even higher rate (Rousta & Ekström, 2013).

Several companies have started to integrate sustainable approaches and have significantly contributed to waste management. Brisbane Day Surgery, who diverted their disposal systems of clinical materials to increase recyclability, succeeded within redirecting the sustainability of their company within a year of implementation (Climate and Health Alliance, 2023).

This has motivated Brisbane City Council (BCC) to propose a new sustainability initiative aligned to the United Nations Sustainable Development Goals 7, 11, 12, and 13. These goals within themselves consider global issues of non-renewable energy, unsustainable cities, communities, production and consumption, and climate change (To read further into these specific global issues both present and future, see appendix H).

By applying this initiative, the Greater Brisbane area, and community within it, will be more aligned towards a sustainable future. The project within this proposal is a WALI (Waste Awareness and Lifecycle innovation) design able to ensure proper waste management within the Greater Brisbane area.

This is to be completed through the development of an automated waste sorting design, capable of physically separating paper, cardboard and metal from any mixture of waste load.

1.2 PROJECT OBJECTIVES

As previously mentioned, the project's objectives emanate from two distinct movements WALI and the United Nations Sustainable Development Goals. The former presents the importance of innovating with respect to the awareness of proper waste management, and through understanding the lifecycle of the product. These factors contribute to the objectives of having a sustainable design that considers environmental impacts throughout its development and implementation (see Section 3 for more information about sustainable development and Section 4 for integration into the design).

The latter, on the other hand, is further extended into four key goals: 7, 11, 12, and 13. Sustainable Development Goal 7 aims to ensure affordability and renewability of energy. Goal 11 fosters the sustainability of cities and communities, goal 12 promotes the sustainability of economic consumption and production. Finally, goal 13 aims to mitigate or adapt societal practices towards the conditions of climate change (United Nations, 2024). These movements together constitute to the solution of global epidemiological and climate related issues seen within unsustainable systems.

Furthermore, the Brisbane City Council has issued for the product to be portable and flexible, allowing for it to be easily integrated throughout a variety of locations, increasing its impact on the chosen location. Aligning the project further to each of the sustainable development goals.

1.3 INITIATIVE DESCRIPTION

The automated waste sorting system proposed in response to the objectives of WALI and United Nations Sustainable Development Goals, and the initiatives set out for proper waste management by BCC, will contribute to the system of recycling within the Greater Brisbane area.

The significance of this contribution within the scope of this project can be seen within the statistics of recycling paper. By just recycling one ton of paper, 13-17 trees, 26498 litres of water, and 4077kWh of electricity are all conserved (Clean up Australia, n.d.). Not to mention that this product will also impact the conservations related to ferromagnetic metals, and cardboard. Furthermore, as mentioned in the context of this project, inappropriate waste disposal and processing have been a cause of rapid spread of diseases and depletion of the ozone layer. This product with its automated functionality of appropriate disposal will pave the way towards limiting these global issues.

With the system's main function of increasing the efficiency of recycling, its positive impacts upon renewable energy, sustainable consumption and production, and mitigation of climate change and disease spread, will develop not only within its own manufacturing and implementation processes, but also within surrounding projects'.

This allows the project to foster macroeconomic sustainability, which when implemented within a larger city or community will promote further awareness of appropriate waste management. Lastly, if all these factors are combined with a production model that considers sustainable development within the design, the design would attain to all contextual initiatives.

2 REAL WORLD PROJECT

2.1 PROJECT LOCATION

Eagle Farm, located in Brisbane's inner- east was selected as the trial location for the waste segregation prototype. The industrial-commercial suburb is known for its concentration of warehousing, freight handling, and manufacturing facilities; making it an ideal location due to its excess waste production. The area is characterised by job roles such as pick-packers, warehouse labourers and machine operators, which contribute to a consistent output of packaging and manufacturing waste. The waste includes cardboard, metal, plastics and paper; closely aligned with the types of waste our prototype has been designed to handle. Eagle Farm's positioning greatly strengthens its suitability. Situated near Brisbane Airport and major road corridors like the Gateway

Motorway; this is great for transport connectivity. This infrastructure supports scalable waste collection and recycling efforts.

Eagle Farm is an industrial suburb located in Brisbane, Queensland, Australia. As of the latest data, it has a relatively small residential population of around 2,000 people, with the majority of the area dominated by commercial and industrial activity. The suburb is known for its warehouses, manufacturing plants, logistics centres, and proximity to the Port of Brisbane and Brisbane Airport. Most users in Eagle Farm are workers and employees in industries such as freight, distribution, machinery operation, and warehouse logistics. With a high presence of pick-packers, forklift drivers, factory staff, and transport operators commuting into the area daily. Due to this industrial focus, community infrastructure is minimal, and the area is more tailored for commercial use than residential living.

Social factors include:

Low Residential Population
Eagle Farm has a small permanent population, so there is limited social infrastructure such as schools, parks, or healthcare centres. This affects the level of community interaction and services.

Worker-Dominated Demographics
Most people present in Eagle Farm during the day are workers — particularly in logistics, transport, and manufacturing. This creates a transient, work-focused environment with limited long-term social cohesion.

Limited Access to Community Services
Since it is largely industrial, residents and workers must often travel to neighbouring suburbs like Hamilton or Ascot for schools, medical services, and recreational facilities.

Environmental factors:

Industrial Pollution
Eagle Farm's concentration of warehouses, freight depots, and manufacturing facilities contributes to air and noise pollution, particularly from heavy vehicle traffic and machinery operation.

Proximity to Brisbane River and Port
Located near the Brisbane River and Port of Brisbane, Eagle Farm is part of an ecologically sensitive area. Industrial runoff and waste management are major concerns for protecting local waterways and marine habitats.

Heat Island Effect
With minimal green space and extensive concrete, metal, and asphalt surfaces, Eagle Farm experiences the urban heat island effect, making it hotter than surrounding residential suburbs.

Centralised waste collection systems are already widely used in Eagle Farm's Commercial facilities. Many warehouses and distribution centres included centralised bins, large waste holding areas, and loading docks that can easily integrate a portable prototype to distribute waste without disruption to existing operations. As seen in figure 1 (image below), most industrial facilities will use basic distribution of waste into two categories: waste and recyclables. This is great to integrate the protype with as we can benefit from waste already being removed from the equation, leaving our prototype to handle paper, metal and cardboard.

Figure 5: Waste and Recycling bins

From a broader perspective, tackling the industrial aspect of Eagle Farm means direct work on the largest quantity of recyclable waste available. As Brisbane aims to grow for the upcoming 2032 Olympic Games, initiating sustainable waste management in logistics heavy zones like Eagle Farm makes a great contribution and can set a trend for nearby areas to improve. As seen in figure 2 (image below), Eagle farm is just west of the airport; a substantial waste production zone due to the high flow traffic of people and tourism. If our prototype can make a good example of its benefits in Eagle Farm, it can later be integrated to the airport and make a considerable contribution to recycling goals.

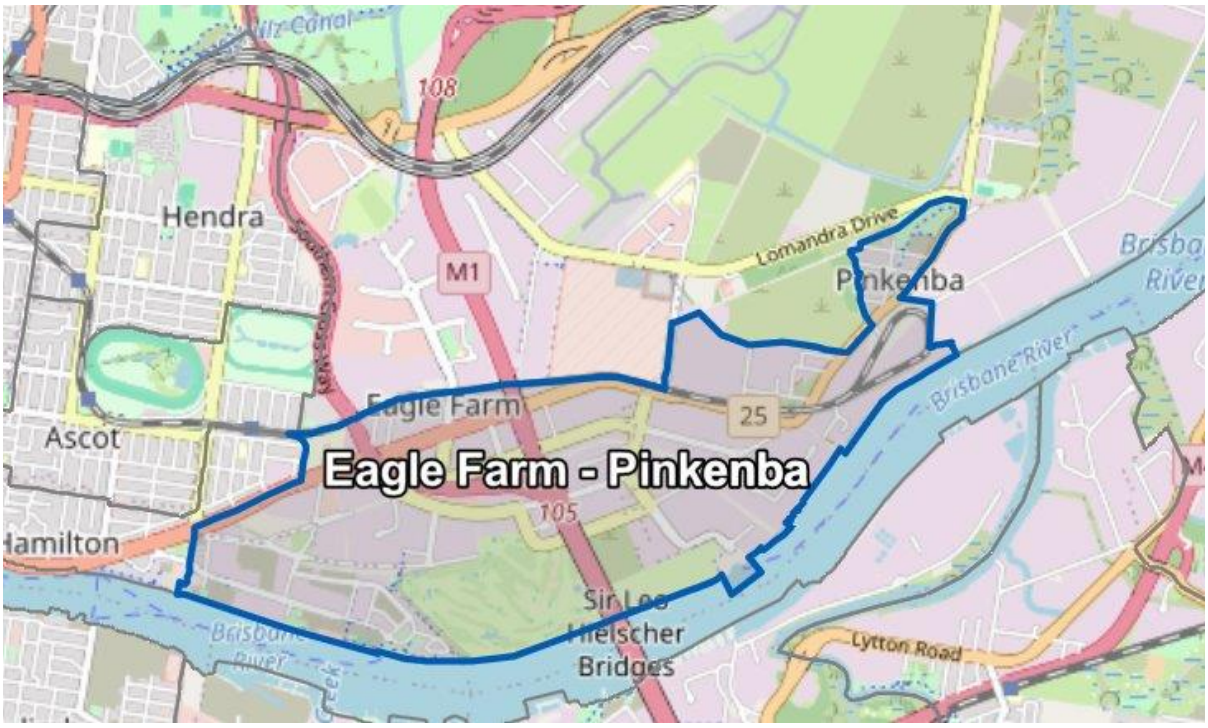


Figure 6: Map of Eagle Farm Area

2.2 DESIGN FEATURES

WALI Key Features

WALI (Waste Awareness and Lifecycle Innovation) is an automated, low-energy waste sorting system designed to streamline and improve the recycling process of three specific waste types: paper, cardboard, and ferrous metals. Developed as part of Brisbane City Council's sustainability initiative, WALI integrates smart use of physics and material science into a compact and environmentally responsible design.

Passive Gravity-Fed System for Energy-Free Sorting

Central to WALI's operation is its inclined plane, which forms the foundation for a gravity-fed sorting process. Waste is introduced at the top of the slope and naturally flows downward without the need for motors or pre-stored energy. This design prioritises simplicity, mechanical reliability, and sustainability by leveraging gravity—a free and renewable force—for waste transport.

Aerodynamic Separation of Paper Using Targeted Airflow

As materials descend the incline, lightweight paper is separated from the stream by a strategically positioned fan producing airflow at 9.87 m/s. This airflow deflects the paper off the main path into a designated collection area without physical contact or damage. The fan is powered by a small battery that may be charged using clean sources such as solar energy, maintaining low energy use and alignment with sustainable practices.

Magnetic Extraction of Ferrous Metals
Further down the slope, a neodymium magnet captures ferrous metals within a 30 mm attraction radius. Positioned adjacent to the sorting path, this passive separation method efficiently diverts metals without mechanical movement or added energy input. Metals are pulled from the stream and collected separately, reducing contamination in the cardboard stream.

Natural Flow of Heavier Cardboard to Endpoint
Heavier, non-ferrous and non-aerodynamic materials—primarily cardboard—continue undisturbed along the slope to the final collection zone. This clear, three-way separation process eliminates the need for complex mechanisms while maintaining high accuracy in sorting.

Sustainable, Durable, and Lightweight Construction
Every material used in WALI was selected with sustainability in mind. The frame is built from aluminium, offering a strong, lightweight structure that resists corrosion and is fully recyclable. Natural rubber, ethically sourced and used for friction-enhancing surfaces, prevents material bounce or slippage. High-density polyethylene (HDPE) forms the casing and support elements due to its recyclability, strength-to-weight ratio, and environmental resilience. Total system mass remains under 1.5 kg, meeting design constraints without sacrificing durability.

User Guarantees from WALI

Minimal Energy, Maximum Impact
WALI was engineered to function with negligible energy requirements. By combining gravity-fed design with passive and highly efficient active separation components, the system dramatically reduces energy use compared to traditional motor-driven sorters. When energy is used—such as to power the fan—it can be sourced renewably through solar panels, ensuring ongoing environmental alignment and minimal carbon footprint.

Quiet, Community-Friendly Operation
Because WALI relies primarily on passive methods like airflow and magnetism, it generates very low noise levels. The single powered component—the fan—runs at a consistent, quiet output that does not contribute to noise pollution, making the system ideal for urban or sensitive deployment locations.

Effective Sorting of Multiple Waste Types
WALI delivers reliable separation of paper, cardboard, and metals—improving recycling efficiency while reducing contamination across waste streams. The internal geometry, airflow vectoring, and magnetic positioning are carefully tuned for precision without damaging the waste materials, which helps maximise resource recovery value.

Environmentally Responsible from Start to Finish
Lifecycle sustainability is at the core of WALI. From recyclable and ethically sourced materials to

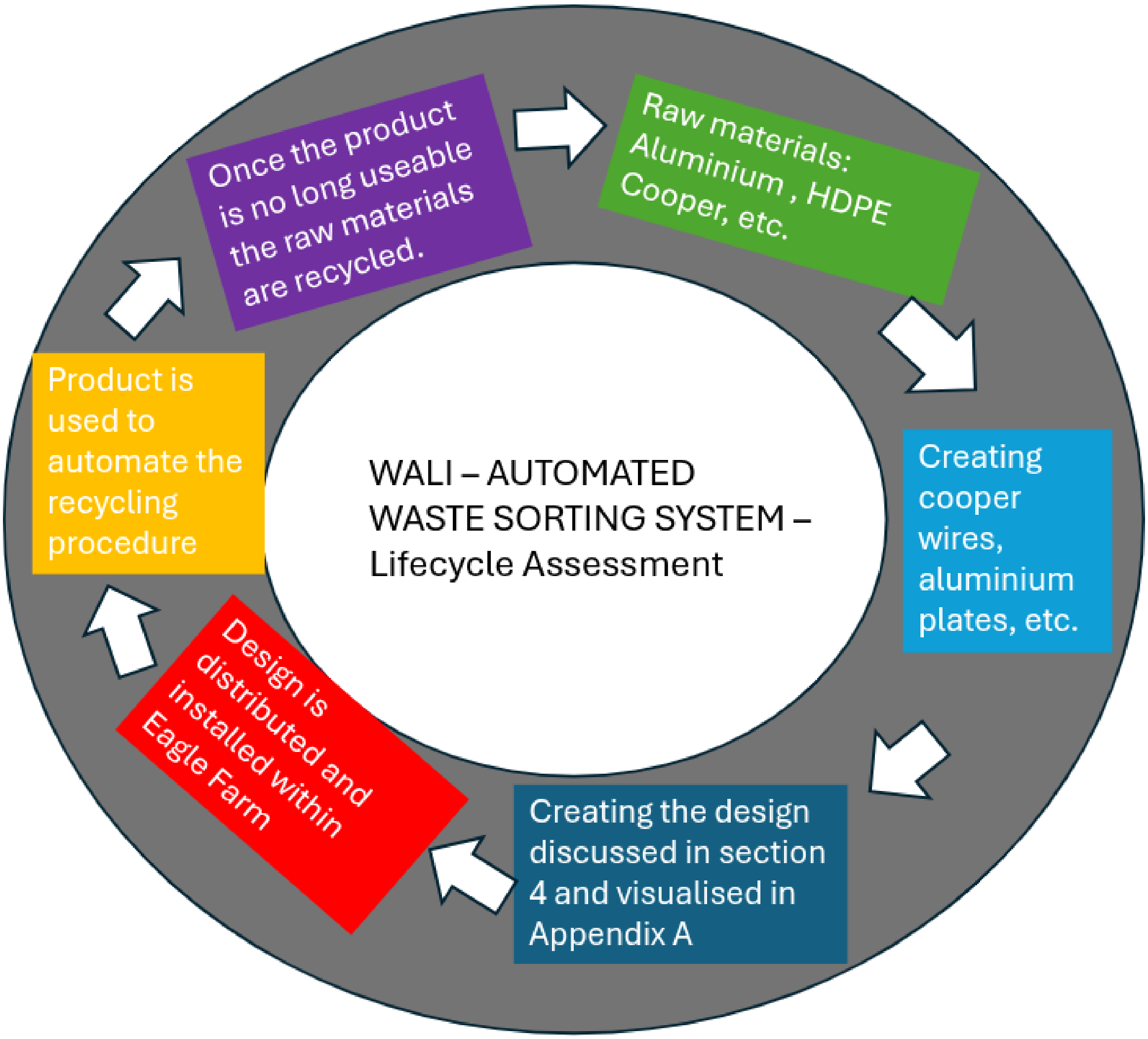
energy-efficient operation and ease of disassembly, every component is chosen to reduce environmental impact. The entire system can be dismantled and repurposed, with minimal waste generated at end-of-life.

Scalable, Cost-Effective Solution for Urban Waste Challenges

Compared to mechanical or labour-intensive alternatives, WALI offers a highly economical and scalable solution. Its passive design means lower manufacturing and maintenance costs, while improving processing time to under 20 seconds per cycle. These features make it well-suited for large-scale rollouts in industrial areas like Eagle Farm, as well as in community recycling initiatives.

3 PROJECT SUSTAINABILITY

3.1 PROJECT LIFECYCLE



The lifecycle of the real-world project shows the stages of impact of the materials needed to build the prototype and where those materials end up. This lifecycle diagram shows the stages of the real-world WALI projects lifecycle from materials, manufacturing, installation to disposal.

The real-world project steps are the following: it begins with the raw materials which are used to manufacture the specific parts of the design like aluminum, HDPE, copper, and others which are made into the necessary systems like the electronics, external structure, containers and key design features. The specifics around these materials are further outlined in sections 3.2 and 3.3.

These parts then are put together to construct the design discussed in section 4 and visually shown in Appendix A. Following the construction of the model, the finished product is installed within the specified area of Eagle farm specified in section 2.1, where it can be moved easily to different locations due to its design being portable through the usage of a truck.

After the systems installed it will automate the recycling process and, once the design is no longer usable the parts will be separated, and all the recyclable parts will be recycled back into raw materials or used in another way as all materials were as recyclable as possible as discussed in section 3.2 and section 3.3.

3.2 MITIGATION MEASURES AND SUSTAINABILITY IMPROVEMENTS

For each key part of the design for the real-world project the most sustainable option was made to minimise negative impacts while maximising the positive impacts. This includes the materials used for each specific part consisting of the conveyer system, incline plane, external structure, containers and the electrical equipment.

Conveyer belts are made from five main materials, metals, thermoplastics, fabric, rubber, and leather with rubber being most popular as it’s a “flexible, resistant, smooth and seamless” material (ConBelt, 2019). There are two types of rubber: natural and synthetic rubber. National rubber is extracted from latex found in rubber tree, most commonly from Hevea Brasiliensis' which is a plant predominantly cultivated in the Southeast Asian region while being native to South America, being extracted using a process called tapping (Rainforest Alliance, 2012).

The environmental effect of natural rubber is its production “is often associated with deforestation which has implications for biodiversity, carbon storage and the climate resulting in the release of carbon dioxide” (Seals Direct, 2024). Also, a majority of natural rubber production is conducted in “unsafe working conditions, a lack of safety standards, inadequate use of toxic chemicals … , long working hours, child exploitation, and problems with migrant workers” (Saksena, 2024). While the negatives of synthetic rubber are that its production is highly-energy intensive, using oil-based feedstock mainly crude oil which extraction involves drilling creating environmental concerns surround pollution (Khatun, 2023).

Furthermore, it has a non-biodegradable nature creating landfill and ocean pollution creating impacts on ecosystems and biodiversity. Finally, it “releases significant greenhouse gas emissions”, with its production including the use of hazardous chemicals (Khatun, 2023). However, rubber can be recycled using proper methods with the most appropriate type being natural rubber if it is handled properly being conducted in a good working environment.

This analysis is backed up by Xuancheng Grand Rubber and Sealing Technology a Chinese manufacturer which says how the carbon footprint of natural rubber depends on how its sourced like if it's from sustainable plantations the carbon footprint is minimal (Xuancheng Grand, 2024). Furthermore, it outlines how natural rubber when sourced responsibly, "is a biodegradable, renewable resource that is more environmentally friendly [while] Synthetic rubber generally has a larger carbon footprint due to the energy-intensive production process .... Additionally, it is non-biodegradable, which creates waste issues" (Xuancheng Grand, 2024).

The real-world project includes an inclined plane where materials would slide down to be sorted. For this to work the material used needs to be durable and sustainable while having a low coefficient of friction to ensure no material comes to rest. The most appropriate material for this would be a type of polished metal which is strong and durable while having a low coefficient of friction.

A potential solution to this is to use Polytetrafluoroethylene (PTFE) which is a type of synthetic fluoropolymer of tetrafluoroethylene as a coating. However, it is limited by its low abrasion resistance making it not applicable as it would need to be replaced often (Holscot, 2019). A more appropriate solution is 'Tricolit® GO' a type of "graphene fortified low friction coating for ceramics, aluminium, bronze, steel and cast iron" having the positive of having a high abrasion resistance (tribonex, 2022).

Furthermore, it was designed to be sustainable being made from a "water-borne formulation with zero VOC emissions". This referring to how it uses water instead of harmful chemicals in its manufacturing which is more environmentally friendly (tribonex, 2022). The most appropriate material would be aluminium which is further proved later in section 3.2.

For the electrical components of the design, copper wire will be used while it has its sustainability concerns surrounding its mining as it is a highly conductive metal which can efficiently transport electricity while not overheating (Copper Sustainability Partnership, 2023).

This is outlined by Federal Metals which explains how "copper mining can severely damage the environment through deforestation … [in] an open-pit mining operation, copper miners must remove trees and dig a pit to access it" (Federal Metals, 2022). Furthermore, it can cause water pollution and release toxic chemicals in the nearby area (Federal Metals, 2022).

This therefore raises issues surrounding two conditions of sustainability of environmental and human. However, this is contradicted by how copper is 100% recyclable being one of the "few materials that can be recycled repeatedly without any loss of performance" limiting its environmental impacts (International Copper Association, 2022).

To limit repairs copper wire can use cellulose insulation which will limit degradation being sustainable as it's made from 85% recyclable materials with minimal energy consumption in its manufacturing (Green Fiber, 2023).

The external structure of the real-world project is constructed from a sustainable, strong non-degradable material. An appropriate solution for this is aluminium which is a durable and strong material which does not rust or corrode being infinitely recyclable (The Aluminium Association, 2021). The environmental benefit of aluminium is that while it requires significant energy in the extraction process of the mineral's "advancements in technology have led to more efficient extraction methods and the use of renewable energy sources, reducing the carbon footprint of aluminium production" (Aston Architectural Aluminium, 2023).

While it's manufacturing also needs an excess of energy the recycling properties limit this as long as it's disposed of properly (ASM Metal Recycling, 2021). Furthermore, according to statistics from Daily Metal Prices, aluminium is an economically suitable solution with the price per kg is going between $2700 to $2300 throughout 2025 as seen in Appendix G (Daily Metal Prices, 2025).

The collections containers and fans were made from High-density polyethylene (HDPE), a material with a high strength to density ratio, considered as the most environmentally friendly plastics not releasing any harmful emissions (Arete Industries, 2015). HDPE has a low energy consumption in its production being highly recyclable material being commonly made into plastic lumber and composite wood (Arete Industries, 2015).

Along with these sustainability positives its properties ensure it needs low maintenance as explained by Industrial Plastics it's a highly durable material with "high chemical and impact resistance … being immune to rust, rotting, insects, mildew, and mold" (Industrial Plastics, 2018). Furthermore, the HDPE global market is increasing as seen in statistics from Statista in Appendix F, therefore meaning it will become even more cost effective as the industry grows, increasing the materials sustainability.

3.3 COMPLIANCE WITH THE FOUR CONDITIONS FOR SUSTAINABILITY

TABLE 3. SUSTAINABILITY COMPLIANCY TABLE

System Condition	Lifecycle Phase	Compliance	Details
1. Reduce extraction of Earth's crust materials	Materials & Production	Partial	Any recyclable material can be re used rather than forced to extract more from the earth. The constant increase in production will always increase the demand of materials.

2. Avoid increasing substances produced by society (e.g. emissions, plastic)	Operation & Disposal	Good	Low-energy motors and clean battery sources reduce pollution and support a low-carbon lifecycle.
3. Protect natural ecosystems and avoid degradation	Manufacturing & Operation	Strong	Reducing the need of extracting materials helps avoid destruction of ecosystems. Reducing landfill means less garbage on the ecosystem
4. Support people's capacity to meet their needs	Community Impact & Use	Strong	Quiet, low-maintenance, user-friendly system; cost-effective alternative to landfills increases community value.

The real-world solution considers the four conditions for Sustainability concerning human, social, economic and environmental. This is seen by how all the materials used for the real-world solution consider its environmental footprint as discussed in section 3.2. Furthermore, as described in 3.1, natural rubber production does have concerns about the human condition of sustainability with working-conditions and the fumes and dust released, so the design will use rubber collected from sustainable plantations (National Library of Medicine, 2012). The materials chosen also were decided on considering price as seen in 3.2. Overall, the design fosters the use of recycling for the local area of Eagle farm contributing to the sustainability of the project with the social condition.

4 PROTOTYPE DESIGN MODEL

4.1 RESEARCH AND DESIGN DEVELOPMENT

The automated waste sorting system required the functionality of segregating paper, cardboard, and paper clips (metal) from a single local entry point where these materials were initially mixed. For this to occur, a unique characteristic of each material had to be identified and manipulated to ensure their successful individual separation.

Research into existing waste separation technologies revealed that magnetic separation and aerodynamic sorting are well-established methods in both industrial and municipal waste management settings. Magnetic systems are commonly used for extracting ferrous materials from mixed waste streams (GCRABB, 2022), and fans or air classifiers are used to separate light materials like paper and plastic from heavier items. Drawing inspiration from these precedents, the team tailored a compact and energy-conscious version of these systems suitable for the project's scope and constraints.

The most obvious distinguishing property among the three materials was ferromagnetism, present in the paper clips. This lent itself naturally to the implementation of a magnetic system. The second material, paper, presented a more subtle yet exploitable difference: its relatively small drag coefficient and lower mass.

This informed the consideration of a fan-based aerodynamic separation system. Lastly, cardboard—heavier than paper and unaffected by magnetism—would remain the only material not influenced by either system, therefore eventually reaching its own segregation point through consistent mechanical motion. This overall motion could be enabled through gravity and assisted by mechanical means such as conveyor belts to ensure that all materials pass through each separation stage effectively.

Considering these material-specific properties and functional requirements, the team developed an initial design comprising three main systems: a magnetic separation section, a fan-based paper separation system, and an overarching transport system to carry the materials through each stage. This transport mechanism was originally conceptualized using a combination of a vertical drop and a horizontal conveyor belt.

In this initial configuration, a vertical chute embedded with a magnet would first separate the metal paper clips, allowing gravity to aid their attraction to the magnet while enabling paper and cardboard to proceed. These two materials would then transition to a horizontal conveyor belt, which would carry them through a fan system. The fan would direct a targeted airflow across a rectangular cross-section, blowing the lighter paper into a designated collection area, while the heavier cardboard would continue to travel to the end of the conveyor for its own collection.

However, through theoretical analysis and initial prototype testing, certain design challenges became apparent. Firstly, for the magnetic separation to be truly effective, the distance between the magnet and the falling paper clips needed to be minimal. This clashed with the need for the vertical section to be wide enough to prevent material clogging. To address this, the team re-evaluated the system layout and chose to reverse the order of the paper and metal separation stages. This adjustment allowed paper to be removed earlier in the system, thus enabling a narrower chute and permitting the magnet to be positioned closer to the metal waste for more efficient attraction.

Furthermore, the vertical section was transformed into an inclined plane. This not only optimized the influence of gravity on material motion but also provided finer control over the rate and direction of descent. The inclination allowed materials to spread more uniformly and reduced the risk of jamming while making the magnetic collection more reliable.

This redesigned system was then physically built and tested. During this testing phase, two critical factors emerged as central to the project's direction: time efficiency and sustainability. It was observed that the conveyor belt system posed recurring challenges in terms of energy consumption and mechanical maintenance. Despite testing various gear ratios and transmission methods, these problems remained unresolved. The conclusion was that the conveyor system, while functional, lacked the sustainability required for long-term use, particularly within the constraints of low-energy operation.

In response to this, the design evolved once more—this time toward a more elegant and energy-efficient solution that eliminated the need for the conveyor belt altogether. The final system design retained the incline plane but introduced strategic physical interventions to manage the flow and separation of materials.

In this configuration, paper is still separated first, but now via a height-based differentiation. As materials slide down the incline, a horizontal metal rod placed perpendicularly across the incline halts the motion of the lightweight paper, causing it to accumulate at the barrier. A fan positioned adjacent to this rod then blows the collected paper laterally into its designated area, eliminating the risk of blockage. Meanwhile, the heavier cardboard and metal components continue sliding down the incline. The magnetic system is positioned downstream, where it attracts the paper clips to its surface, completing the final stage of separation.

This final design significantly improved sustainability by relying solely on gravity and minimal electrical input from the fan and magnet. Additionally, it enabled simpler maintenance while preserving the distinct separation mechanism for each material. The thoughtful evolution of the design—rooted in both research and practical testing—ultimately led to a more efficient, reliable, and sustainable waste sorting system.

Below is a design evaluation matrix that takes each stage of the design development and rates the ability for the models to segregate paper, cardboard, and metal, the efficiency of the resources used, and whether the materials could flow through the model without being damage or requiring prestored energy.

For the former criteria, this was judged based on testing and theorising on a model's precision and possible events that could cause the model to become ineffective. Whereas the latter criteria – which also come from contextual requirements – were based on whether the model was overcomplex or had potential to damage the material in any sort of way.

TABLE 4. EXAMPLE DESIGN EVALUATION MATRIX

	Separates Paper	Separates Cardboard	Separates Metal	Resource Efficiency	Does not damage material and does not use	Total Score

					prestored energy	
Vertical magnetic section connected to horizontal conveyor belt and fan system	1	1	1	3	2	8
Horizontal conveyor belt and fan system connected to incline magnetic section	3	3	3	3	3	14
Incline plane with perpendicularly bisected metal rod followed by magnetic section	5	5	5	5	4	24

**Note: Scores are ranked where 5 means the design meets this criterion well and 1 means the design does not meet this criterion.*

As can be seen the initial model scores the lowest for the separation criteria as it does not allow for any of the materials to be separated with an ineffective vertical chute that clogs. This could also be a point where the materials are damaged.

Furthermore, it scores low in resource efficiency as it acquires a conveyor belt that was evaluated as a waste of electrical energy through friction and other inefficiencies causing limited mechanical output and could also be a point where the materials can be damaged due to the ability to malfunction and the fan systems.

This last point carries onto the second model, which with consideration to the inefficiencies and maintenance issues of the conveyor belt section was evaluated as having a medium rating in the ability to separate the materials, resource efficiency, and to keep the materials undamaged.

Lastly, the final design was evaluated as having the best ratings of material segregation and resource efficiency. Due to relying on a more effective characteristic of paper that allows for the conveyor belt system to be removed. However, it stills applies a fan system that does have the potential to damage the materials and so it lost a rating in that criterion. (See appendix A for initial and final sketches)

4.2 FINAL MODEL DESIGN

Sketches for whole schematic, electrical, mechanical, and structural design can be seen with appendix A.

4.2.1 Technical Design

The functionality of the system is to accept an input of three distinct waste types—paper, cardboard, and paper clips (metal)—and autonomously output each material into its respective collection zone through a combination of passive mechanical sorting, strategic use of magnetic and aerodynamic forces, and simple electrical control. The design integrates structural, electrical, and mechanical systems into a single cohesive unit that prioritizes efficiency, compactness, and reliability.

At the heart of the system is a polished stainless steel incline plane, tilted at approximately 14.5°, forming the primary sorting track. Waste materials are inserted through a receiving inlet located at the top of the incline. From here, gravity initiates the downward motion of all components along the low-friction surface. As the waste descends, each item is exposed to a sequence of sorting mechanisms based on their physical properties—mass, magnetic permeability, and aerodynamic response.

The first key functional component is the fan system, which is powered by a 5V DC motor connected to a lithium-ion battery via a manual switch mounted externally on the system's aluminium enclosure. To ensure that only the paper (mass: 2g, area: 7 cm²) is laterally deflected without disturbing the cardboard (3g, 2 cm²) or paper clips (2g, 2 cm²), the fan must generate a drag force that exceeds the paper's gravitational force:

$$Fg = mg = 0.002kg \times 9.81m/s^2 = 0.01962N$$

Using the drag equation:

$$Fd = \frac{1}{2}\rho v^2 C_d A$$

Solving for the required air velocity v when $Fd = Fg$:

$$v = sqr\left(\frac{2Fg}{\rho C_d A}\right) = sqrt\left(\frac{2 \times 0.01962}{1.225 \times 0.47 \times 7 \times 10^{-4}}\right) \approx 9.87m/s$$

Thus, the fan must produce an airflow velocity of at least 9.87 m/s to deflect the paper, assuming a near-spherical crumpled shape (drag coefficient ≈ 0.47). This ensures the cardboard and metal components remain unaffected due to their smaller exposed area and/or greater mass.

Incline Plane and Friction Calculations

To allow all materials to slide under gravity, the net force acting on each object must be positive in the direction of motion:

$$F_{net} = mg\sin(\theta) - \mu mg\cos(\theta) > 0$$

This simplifies to:

$$\tan(\theta) > \mu$$

At the set incline of θ=14.5∘, the maximum allowable coefficient of friction μ is:

$$\mu_{max} = \tan(14.5) \approx 0.259$$

Hence, the surface finish of the incline must provide a coefficient of friction less than 0.259 to ensure all three materials (2g and 3g) slide freely.

Magnetic Separation: Paper Clip Attraction Distance

The neodymium magnet used (dimensions: 58mm × 22mm × 10mm) is embedded behind a diagonal guiding wall. Empirical testing confirmed that this magnet can reliably pull 2g metal paper clips from a maximum distance of 30mm. To justify this in terms of force:

$$Fg = mg = 0.002kg \times 9.81m/s^2 = 0.01962N$$

Provided the magnetic force at 30 mm exceeds 0.0196 N, the separation will be successful. The design ensures the metal paper clips approach the magnet within this threshold, while non-ferromagnetic materials remain unaffected.

Continuing along the incline, the fan is mounted above the incline and slightly offset laterally, ensuring that only the paper is deflected into its sorting tub. The paper, upon reaching a perpendicular metal rod placed in the path of descent, is halted and then redirected sideways by the fan. The remaining materials continue to descend toward the magnet.

Cardboard, too heavy for the fan and unaffected by magnetic forces, proceeds directly into its designated zone. Angled aluminium walls further enhance directional guidance into narrowed collection channels, reducing misalignment or deflection due to minor irregularities.

All electrical components—including the 5V fan motor (~1.8 A), lithium-ion battery, and manual switch—are wired in a simple series circuit for ease of maintenance and reduced energy loss. Electrical terminals and ports are clearly labelled and securely mounted within the enclosure to prevent disconnection.

A dimensioned system sketch complements this report, demonstrating precise placement of each component and their integration. The drawing includes elevation and top-down views of the incline plane, aerodynamic module, magnetic separator, and final collection bins.

This final version of the design capitalizes on natural forces like gravity and material properties, minimizing reliance on complex actuators or high-energy systems. The result is a robust, maintainable, and sustainable solution for autonomous waste segregation with minimal moving parts.

4.2.2 Structural Subsystem design

The structural subsystems of the waste sorting system are designed to maximize mechanical efficiency, material separation accuracy, and physical integrity under low-energy conditions. At the core is a polished stainless steel inclined plane, forming the primary structural and functional component.

Stainless steel was chosen for its low coefficient of friction and excellent wear resistance, which facilitate unimpeded motion of materials under gravity-assisted flow (ASTM, 2010. The incline's angle was experimentally fixed at 14.5°, balancing the gravitational force required to move paper (~2g), cardboard (~3g), and paper clips (~2g) without inducing uncontrolled acceleration.

A diagonally mounted guiding wall, also made of polished stainless steel, aligns materials toward designated sorting zones. The high surface finish reduces friction-induced deviations in pathing, ensuring predictable motion (*Bhushan, B. 2013).* Behind a precision-cut section of this wall is embedded a neodymium magnet, forming the magnetic capture subsystem. The support structure for the inclined plane is fabricated using steel pillar legs, bolted securely to a baseplate.

Steel was selected for its high compressive strength (~250 MPa for structural low-carbon steel) and modulus of elasticity (~200 GPa), offering stability under operational loads (*Callister & Rethwisch, 2020*). Load testing confirmed the frame could withstand forces exceeding 150 N, well above anticipated static and dynamic loads.

All partitioning and containment walls are constructed from lightweight aluminium sheets, selected for their low density (~2.7 g/cm^3), good corrosion resistance, and sufficient rigidity under light structural stress (Ashby, M. F. 2011). Aluminium's resistance to environmental degradation ensures long-term operation in diverse waste-handling environments with minimal maintenance.

The electric fan housing is structurally integrated into the incline system and braced with thin-gauge aluminium framing to maintain position without compromising weight restrictions or motion of the fan’s blades. Its placement and orientation are fixed using laser-cut slotted brackets, also aluminium, to prevent vibrational shift during repeated airflow activation. Furthermore, the aluminium sheets integrate wire routings through removed sections, allowing the wire to bypass to electrical components.

In total, the structural subsystem integrates materials selected based on mechanical properties, environmental resilience, and mass-efficiency considerations, ensuring the complete assembly remains under the 1.5 kg limit while upholding sorting precision. All structural choices align with core engineering values: simplicity, durability, and energy-efficient performance.

TABLE 5. TESTING OF MATERIALS

Material	Results from testing	Significance	Reference
Steel	- Compressive strength, found to be 250MPa - Modulus of Elasticity, found to be approximately 200 GPa	This grants the steel an ability to withstand the required loads for this project.	(*Callister & Rethwisch, 2020*)
Aluminium	- Corrosion resistant - Rigid under load	Enables sustainability and strength of external design structutre, boosting longevity.	(Ashby, M. F. 2011)

4.2.3 Electrical subsystem design

The electrical subsystem of the incline-based waste sorting mechanism is deliberately minimal, emphasizing efficiency, reliability, and support for primarily passive material separation. The system incorporates five core electrical components: a 5V DC lithium-ion battery pack, a brushed DC fan motor, copper wiring, a manual rocker switch, and a neodymium magnet (passive, non-electrical).

Power Supply:
The system is powered by a 5V rechargeable lithium-ion battery pack, selected for its high energy density, stable voltage output, and compact form. This battery supports continuous operation of the fan motor for over 60 minutes under standard load conditions, making it well-suited for intermittent low-power applications.

Fan Motor:
The system's sole active component is a brushed DC motor rated for 5V, responsible for driving the fan that redirects lightweight paper during sorting. The motor draws approximately 1.8 A under peak

load and was chosen based on airflow testing that confirmed an output of 9.87 m/s, sufficient to deflect 2g paper sheets laterally while leaving heavier items unaffected.

Wiring and Circuit Layout:
Approximately 10 cm of insulated copper wire rated for 3 A current capacity is used to interconnect the components. These wires are routed through integrated channels along the aluminium structural panels to prevent mechanical interference or user contact. The circuit operates in a simple series configuration, ensuring low power loss and ease of assembly.

Switching Mechanism:
A manual rocker switch is installed along the positive terminal of the battery line, enabling controlled activation of the fan circuit. This allows operators to toggle airflow manually when paper detection is visually confirmed, reducing unnecessary power draw and extending battery life.

Magnetic Component:
The neodymium magnet, although critical to material separation, does not require electrical input and is therefore not part of the powered circuit. Its inclusion in the system is mechanical and magnetic rather than electrical in nature.

Testing and Validation:
Electrical performance was validated using a multimeter. Under load, the motor consistently received 5.02V, indicating excellent voltage stability and minimal resistance in the wiring. Both idle and load current draws were measured to assess thermal performance and confirm that the motor operated within safe parameters.

This streamlined electrical design supports the broader engineering objective of low-energy, low-maintenance operation, providing only targeted assistance to the predominantly passive waste sorting system (See appendix A for circuit diagram).

4.2.4 Mechanical subsystem design

The mechanical subsystem of the incline-based waste sorting device is designed for maximum functional simplicity, relying on passive mechanical forces—primarily gravity and magnetism—with minimal moving parts. Its goal is to mechanically guide, separate, and redirect materials (paper, cardboard, and metal paper clips) based on mass, aerodynamics, and magnetic responsiveness without the need for gears, belts, or actuators.

At the system’s core is a polished stainless steel inclined plane, selected for its low-friction surface that promotes smooth, uninterrupted downward motion of materials. Stainless steel's excellent surface finish and wear resistance make it well-suited for repeatable contact-based motion applications (Bhushan, 2013). The angle of inclination was determined through iterative physical testing, with 14.5° identified as optimal for enabling gravitational sliding of materials weighing between 2g–3g, while avoiding overshooting at the separation points.

The fan mechanism—the sole active mechanical device—produces a lateral aerodynamic force that selectively deflects lightweight 2g paper sheets. The fan is mechanically mounted at a fixed height and angle along the incline. Its position was optimized experimentally to produce a directed airflow of 9.87 m/s, which consistently redirected paper while leaving heavier cardboard and metal clips unaffected. Mechanical integration of the fan includes a fixed-angle mount, ensuring consistent airflow direction during repeated cycles. The fan's aerodynamic effect was tested using materials of different surface areas and masses to confirm reliability, achieving a 95% deflection success rate in lab conditions.

Angled aluminium guide walls are mounted along the incline to mechanically funnel materials along constrained paths. Aluminium was selected for its lightweight and corrosion-resistant properties while maintaining sufficient stiffness under low-stress conditions (Ashby, 2011). Mechanical deformation tests using downward force up to 40 N confirmed that the guide walls do not significantly flex or warp under expected operational loads.

A polished diagonal guiding wall is placed laterally along the incline. Its function is to tighten the material stream and align paper clips with the embedded neodymium magnet positioned behind a cut-out zone. The magnet's mechanical integration allows it to passively attract and remove ferrous items from the stream without the need for moving magnetic conveyors. The setup was tested to capture 2g metal clips at a maximum lateral range of 30 mm under dynamic motion.

The system's mechanical simplicity is a critical design principle. No gear trains, gearboxes, or chains are used. All motion is achieved either through gravity, fixed aerodynamic redirection, or passive magnetic attraction. This reduces mechanical complexity, weight, and maintenance demands—key benefits for an energy-efficient and compact sorting system (Callister & Rethwisch, 2020).

5 CONCLUSIONS AND FUTURE DEVELOPMENT

5.1 REAL WORLD RECOMMENDATIONS

While the current waste sorting system achieves its core design goals of simplicity, low energy consumption, and effective material separation through gravity, magnetism, and aerodynamic forces, several real-world limitations must be addressed to ensure practical, long-term deployment.

Portability and integration flexibility are currently limited by the system's fixed inclined structure. To improve adaptability across varied environments, the design could be reconfigured using a modular frame with collapsible joints and lightweight composite materials such as carbon-fiber-reinforced polymers or recycled plastic-aluminum hybrids. Mounting the entire unit on a wheeled, weather-resistant enclosure would further allow for transportation and deployment in schools, community centers, or outdoor awareness campaigns.

The system's dependence on consistent material size and shape poses a significant challenge in real-world waste streams, where input materials vary due to folding, tearing, or contamination. To maintain performance without intensive preprocessing, an adaptive entry stage could be developed—

incorporating a compression roller or adjustable mechanical gate that aligns or flattens materials before sorting.

This passive subsystem would standardize feed dimensions without adding high energy demand, preserving the system's low-power philosophy. However, in industrial applications, limited preprocessing (e.g., flattening cardboard or separating bulky items) may still be necessary, and the economic trade-off should be evaluated based on throughput and labour costs.

The collection and clearing of sorted materials, particularly around the magnetic zone, presents another operational concern. In a real-world context, continued build-up of paper clips on the magnet may reduce magnetic efficiency and create mechanical interference.

To mitigate this, a rotating magnetic drum with a timed pulse of alternating magnetic poles could be introduced, triggered by a microcontroller to periodically release collected metal items into a bin. This upgrade would maintain magnetic integrity over longer periods while remaining energy-efficient, particularly when powered by intermittent triggers rather than constant actuation.

Moreover, the current design lacks an external communication or engagement layer that promotes public awareness of recycling practices. A sustainable external casing, potentially formed from cellulose composite panels with printed pro-recycling messages or QR codes linking to local waste education resources, would transform the system from a purely functional device into a participatory educational tool. Such integration aligns with public sustainability goals and encourages responsible recycling habits.

Environmental robustness also requires attention. Noise and thermal insulation can be improved by lining the enclosure with cotton fibre layers enclosed between corrugated cellulose plates—materials that are both renewable and biodegradable. This not only reduces fan and vibration noise but also provides thermal buffering in fluctuating climates, ensuring stable fan performance and user comfort during handling.

Looking to the future, AI integration and enhanced automation could significantly boost the system's capabilities. A vision-based sensor system combined with microprocessor control can dynamically detect material types and initiate responsive actions—such as activating the fan only when lightweight paper is detected or cycling through the magnetic release system.

A scalable version of the design might integrate conveyor belts for continuous feed and enable handling of larger waste volumes without sacrificing sorting accuracy. These systems could also be linked with IoT monitoring to track usage, efficiency, and maintenance needs remotely, supporting smart city waste management infrastructures.

In summary, by enhancing mobility, addressing material variability, introducing smart magnetic clearing mechanisms, improving environmental resilience, and embedding educational and digital capabilities, the system can evolve from a functional prototype into a practical, community-integrated waste sorting solution ready for real-world impact.

5.2 PROTOTYPE DEMONSTRATION

During the prototype's testing, it underperformed based on the group's assumptions but met the benchmark criteria by maintaining a mass of under 1.5 kilograms, a frame of 30cm x 30cm x 50cm and could mostly sort the recyclables under 20 seconds without intervention. Unexpected problems arose during the testing, to which were quickly fixed or removed. Such cases were the fan needlessly occupying space, since it didn't blow the paper hard enough to move it far enough to prevent it from blocking the entrance to the following stages of the sorting process. Although some of the materials managed to avoid the blockage, most of the materials were still at the paper collection area.

Furthermore, only half of the materials were correctly sorted, which then – when trying to re-test the prototype – led to a second problem of the collection areas being hard to access to retrieve the recyclables. Unfortunately, when trying to stop paper from entering other collection areas, the metal rods were too close together and they weren't at an appropriate angle remove the paper, resulting in a blockage.

Alternatively, paperclips passing the magnet were attracted to the magnet, successfully sorting paperclips from the other recyclables. Moreover – due to the incline of the prototype's slope and its smooth surface – the paperclips weren't stopped by imperfections, organising items in under five seconds, less than a fourth of the minimum time limit. Added deflection zones and collection areas allowed simpler means of sorting recyclables to more easily remove their respective items by slowing them down and to properly identify incorrectly sorted pieces.

More testing was required to gauge the effectiveness of the prototype, given more time, leading to the potential to add a stronger motor with a better gearbox ratio and setup. Due to the system's lack of a powerful motor due to Motor B's inability to move a small load, a stronger motor would be able to drive a conveyor belt. A conveyor belt would be able to more easily provide a strong, constant force to move all the recyclables along, but also allow an easier way to sort paper especially, angling rods to remove paper from the conveyor and above magnets to collect the paperclips. An open prototype; one without any walls or a roof, would allow a more concise and informed viewing of the system, allowing one to easily identify and remedy errors.

To increase usefulness, the design must look outside the given scope to expand its impact on a community. Therefore, some future considerations may include creating a more water-resilient, simple, heat-resistant, and modular design. Hence, this design wouldn't only be able to survive common natural disasters around the Brisbane area like wildfires and flooding, but it would also be easily transported, maintained and operated by people in recently stricken areas by such natural disasters identified above to quickly remove waste to reduce the chances of injuries and epidemics in the region.

6 REFERENCES

You must correctly and appropriately reference your sources using QUT APA style (author, date). Ensure you apply correct in-text referencing and bibliographic formatting and structure as defined by the style. References should be presented in alphabetical order.

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7 APPENDICES

APPENDIX A – TECHNICAL DRAWINGS

Initial and Final Whole Schematic, Structural, Electrical, and Mechanical Design Sketches

APPENDIX B – RISK ASSESSMENT

Group Q - Risk Assessment

APPENDIX C – GANTT CHART

Group Q - Gantt Chart

APPENDIX D – TEAM CHARTER

Group Q - Team Charter

APPENDIX E – MEETING MINUTES

Group Q - Team Meeting Minutes

APPENDIX F

HDPE Statistics

APPENDIX G

Aluminium Cost

APPENDIX H – INTRODUCTION: SUSTAINABLE DEVELOPMENT GOALS’ GLOBAL ISSUES

The following figures come from United Nations, 2024:

Figure 1 – Goal 7

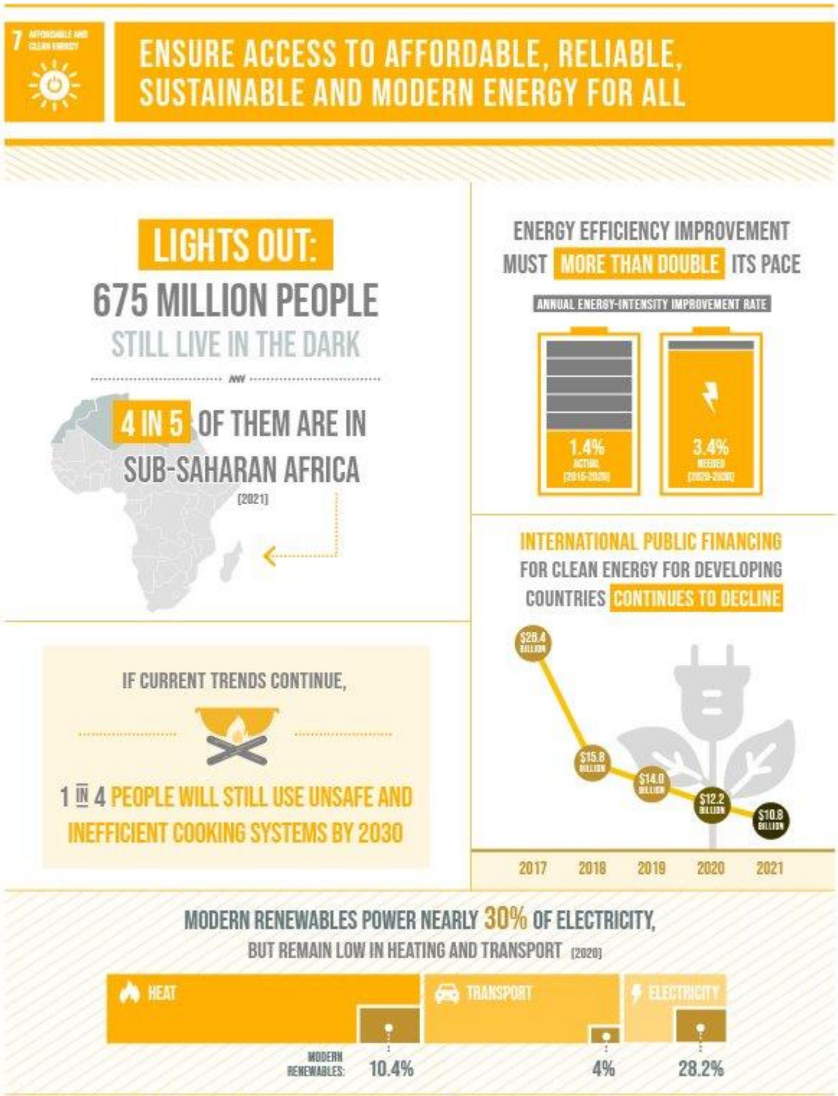

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Figure 2 – Goal 11

Figure 3 – Goal 12

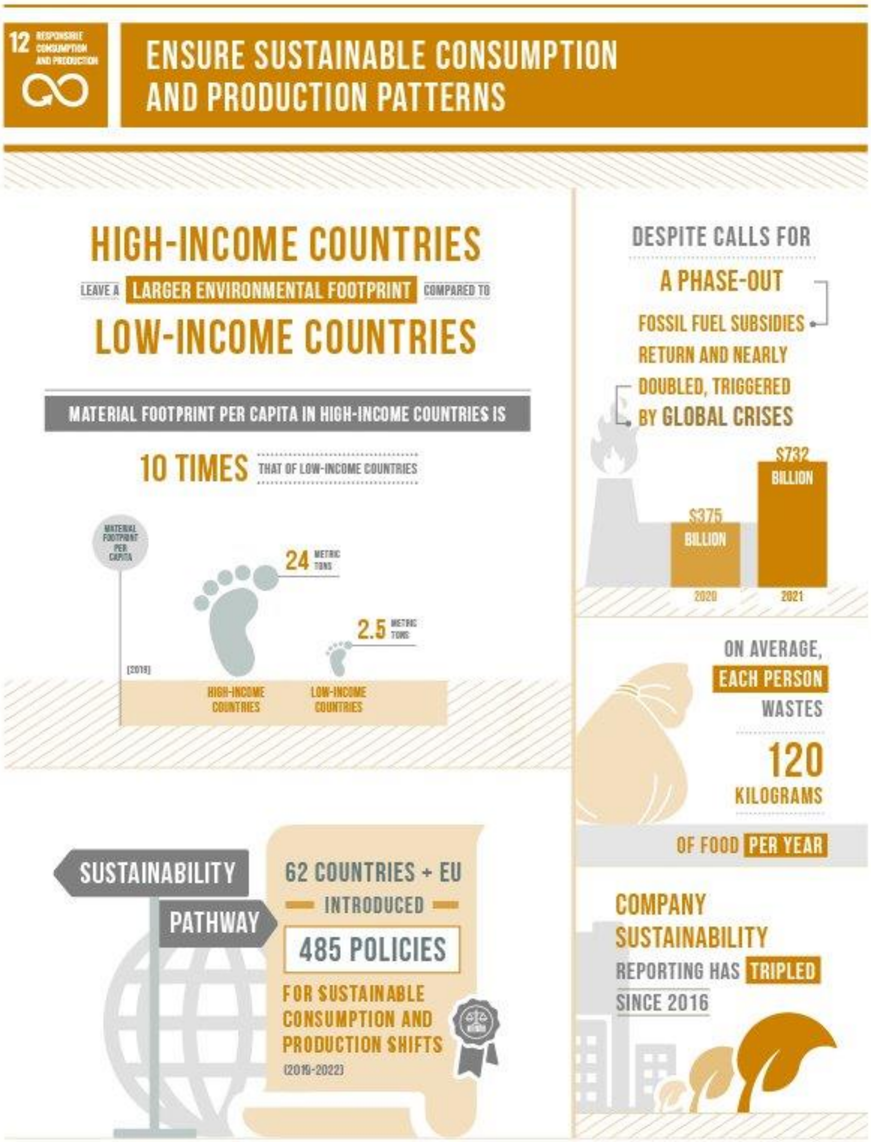

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Figure 4 – Goal 13

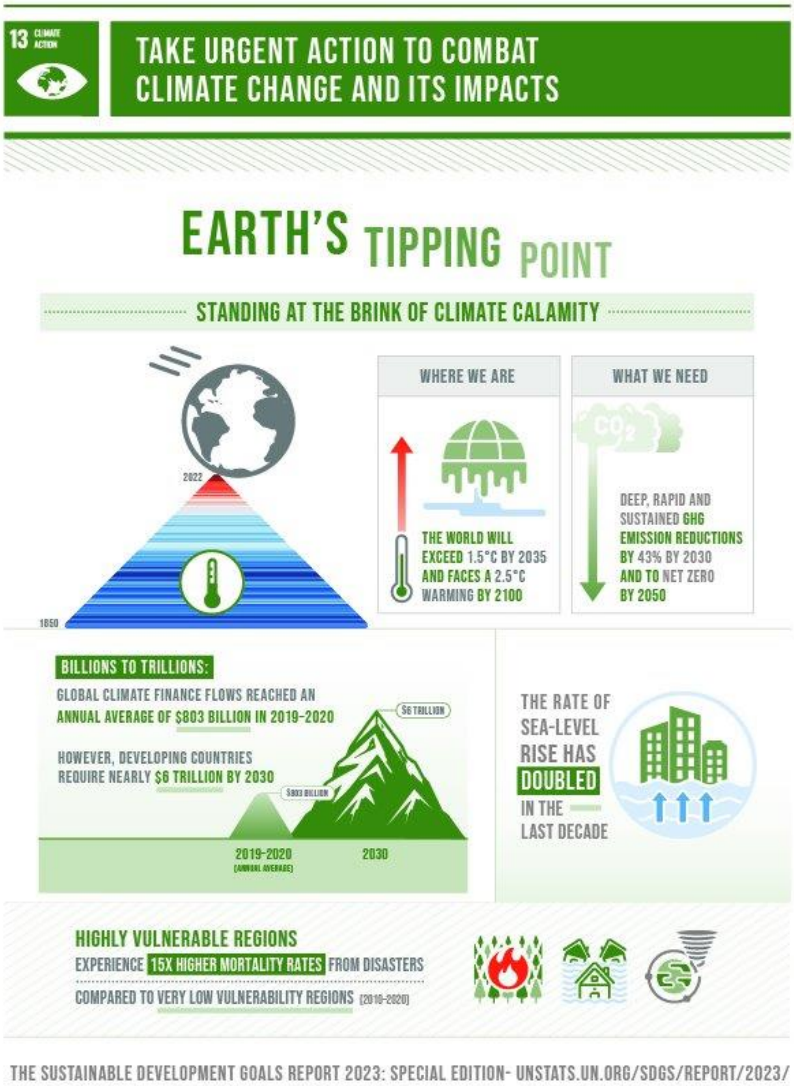

Figure 5- Waste and Recyling bins

Figure 6- Map of Eagle Farm area