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White Paper

Tackling the E-Waste Crisis

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Executive Summary

This white paper addresses the growing challenge of electronic waste (e-waste) in Melbourne, Australia, aligning with Sustainable Development Goal 12 (SDG 12) on responsible consumption and production. We analyse the environmental and health hazards posed by increasing e-waste volumes and consumer e-waste recycling behaviour. The paper examines the current e-waste management system and proposes a solution incorporating innovative technologies, including CERN/ATTRACT technologies, to tackle this crucial issue.

In 2021, Australia generated 650,000 tonnes of e-waste, with Victoria contributing 170,000 tonnes. Of this, 23,800 tonnes were sent to landfills—equivalent to 700 Melbourne trams—while 142,000 tonnes were exported or processed domestically (Victorian E-Waste Material Flow Analysis, Aug 2023). Improper disposal of e-waste leads to environmental and health impacts, exacerbating the problem of already polluted landfills. The increasing release of electronic products suggests a rising trend in e-waste generation.

The team conducted a series of primary (surveys, interviews, and site visits) and secondary research throughout the project to develop a solution.

Our proposed solution, the BLOOM Project, consists of two parts aimed at creating a sustainable recycling system and educating the public about e-waste and its impact. Firstly, BREW, which stands for 'Bioreactor for E-Waste Recycling', is a specially designed large-scale bioreactor used to recover metals from e-waste through bioleaching. This environmentally friendly process uses microorganisms to break down e-waste and recover precious metals. Secondly, BLOOM Experience Hub, an innovation hub designed to educate and engage the community in improving e-waste recycling. It uses augmented reality (AR) and virtual reality (VR) to educate the public and provides a public space for e-waste drop-off and recreational activities to encourage more visitors.

Through BLOOM and BREW, we aim to increase public awareness of e-waste and its impact, changing consumer behaviours towards e-waste recycling, while also enabling the majority of e-waste to be recycled sustainably within Australia, reducing the need for landfills or exporting e-waste for further processing. We also work towards standardising the recycling collection system to improve efficiency. This will reduce the volume of e-waste in landfills and mitigate its negative impacts on health and the environment in the future. The success of this vision for Melbourne, Australia, from 2030 onwards, hinges on certain assumptions regarding technological progress, which act as key drivers for the proposed solutions.

Glossary

AR (Augmented Reality)
A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.

ATTRACT
A European Union-funded program aimed at developing breakthrough technologies for science and society.

Bioleaching
The process of extracting metals from ores or waste by using microorganisms to oxidise the metals, producing soluble compounds.

Circular Economy
An economic system based on the reuse and regeneration of materials or products, especially as a means of continuing production in a sustainable or environmentally friendly way.

CERN
The European Organisation for Nuclear Research, an international scientific organisation, known for its scientific research and technological advancements.

Consumer Price Index (CPI)
A measure that examines the average change over time in the prices paid by consumers for goods and services.

Data Destruction
The process of permanently erasing data from electronic devices before they are recycled or disposed of. This is important to prevent identity theft and data security breaches.

EU (European Union)
A political and economic union of 27 European countries that are located primarily in Europe.

E-waste (Electronic Waste)
Electronic waste are any item with a plug, battery or power cord that's no longer working or wanted. It covers a whole range of items from phones, computers, wire and fridge to fluorescent light tubes.

End-of-Life (EOL)
The point at which a product can no longer be used for its intended purpose and needs to be disposed of.

End-of-Use (EOU)
The point at which a product is no longer being used for its original purpose but may still be functional for other purposes.

Extended Producer Responsibility (EPR)
An environmental policy strategy that holds producers responsible for the end-of-life consequences of their goods.

Metal Recovery
The process of recovering metals from end-of-life products.

Microorganisms
An organism that can be seen only through a microscope, such as bacteria, fungi, and archaea.

NTCRS (National Television and Computer Recycling Scheme)
An Australian program that provides Australian households and small businesses access to free recycling services for televisions and computers.

RoHS (Restriction of Hazardous Substances Directive)
An EU directive aimed at preventing the risks posed to human health and the environment related to the management of electronic and electrical waste.

Sustainable Development Goals (SDGs)
A set of 17 global goals established by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity.

Sustainable Development Goal 12 (SDG 12)
One of the 17 SDG goals set by the United Nations, which focuses on ensuring sustainable consumption and production patterns.

UN (United Nations)
An international organization founded in 1945 to promote peace, security, and cooperation among countries.

VR (Virtual Reality)
A computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using 3D near-eye displays and pose tracking.

WEEE (Waste Electrical and Electronic Equipment Directive)
An EU directive that sets collection, recycling, and recovery targets for electrical goods.

WHO (World Health Organization)
The United Nations agency working to promote health, keep the world safe and serve the vulnerable.

SDG12 & Societal Challenges

The Sustainable Development Goal 12 (SDG12) was created by the United Nations to ensure sustainable production and consumption, which is why the team has decided to tackle and address the SDG12 goal on e-waste. (United Nations, Department of Economic and Social Affairs, n.d.)

Target 12.4
By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil to minimise their adverse impacts on human health and the environment.

Target 12.5
By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

Electronic products have become seamlessly integrated into our everyday lives. From smartphones that facilitate communication to smart home devices that streamline household tasks, these innovations enhance convenience and connectivity, illustrating the pervasive influence of electronic technology over the years. However, the widespread use of electronic products also contributes to the growing challenge of e-waste, highlighting the importance of responsible disposal and recycling to mitigate environmental impacts and health hazards associated with electronic waste. E-waste contains hazardous materials like lead, mercury, and cadmium. These can leach into soil and water, causing severe environmental damage. This contamination can enter the food chain, posing further risks to human health and wildlife. Improper e-waste disposal will also release toxic substances harmful to human health and when in contact, it can cause respiratory, immune and central nervous systems (World Health Organisation, 2023).

Problem Space

Electronic waste (e-waste) refers to discarded electrical or electronic equipment, devices, or their components. This includes any items or parts whose operation depends on or is designed for the generation, transfer, or measurement of electric currents or electromagnetic fields (Environment Protection Authority Victoria, 2021).

"This means any device that has a plug, battery or power cord that is no longer working or wanted. It includes a range of items we use and discard from our homes and businesses" (Environment Protection Authority Victoria, 2021), such as DVD's, mobile phones, freezers, fridges. Electronic products that are thrown away improperly by their owners or manufacturers, can have significant impact on the environment and human health like:

Soil pollution through leaching of toxic elements and effluent discharge from crude recycling techniques like melting, chipping, heating, stripping, and physical dismantling (Rautela et al., 2021).

Water pollution from acidic effluent discharge, washing of circuit boards, and disposing of waste residue into nearby drains, rivers, lakes, or oceans (Rautela et al., 2021).

Air pollution from open burning of circuit boards, emission of toxic fumes, and suspended particulate matter (Rautela et al., 2021).

Current E-Waste Situation in Australia

(E-PRODUCT STEWARDSHIP in AUSTRALIA Evidence Report, 2021)

- In 2019, around 521,000 tonnes of e-waste were generated in Australia, equating to 20.4kg of e-waste per capita.
- Only about a third of the total value of materials in the e-waste generated is recovered, with the rest sent to landfill (worth around $430 million).
- Australia is one of the highest generators of e-waste per capita globally, ranking 5th with 21.7kg per person in 2019.

Projected E-Waste Growth by 2030

(E-PRODUCT STEWARDSHIP in AUSTRALIA Evidence Report, 2021)

- The amount of e-waste in Australia is projected to rise by nearly 30% to 674,000 tonnes by 2030.
- While e-waste from TVs and computing equipment is expected to decrease by 32%, there will be significant increases in e-waste from temperature exchange equipment (+66%).
- The per capita e-waste generation is projected to increase to 23.4kg by 2030.

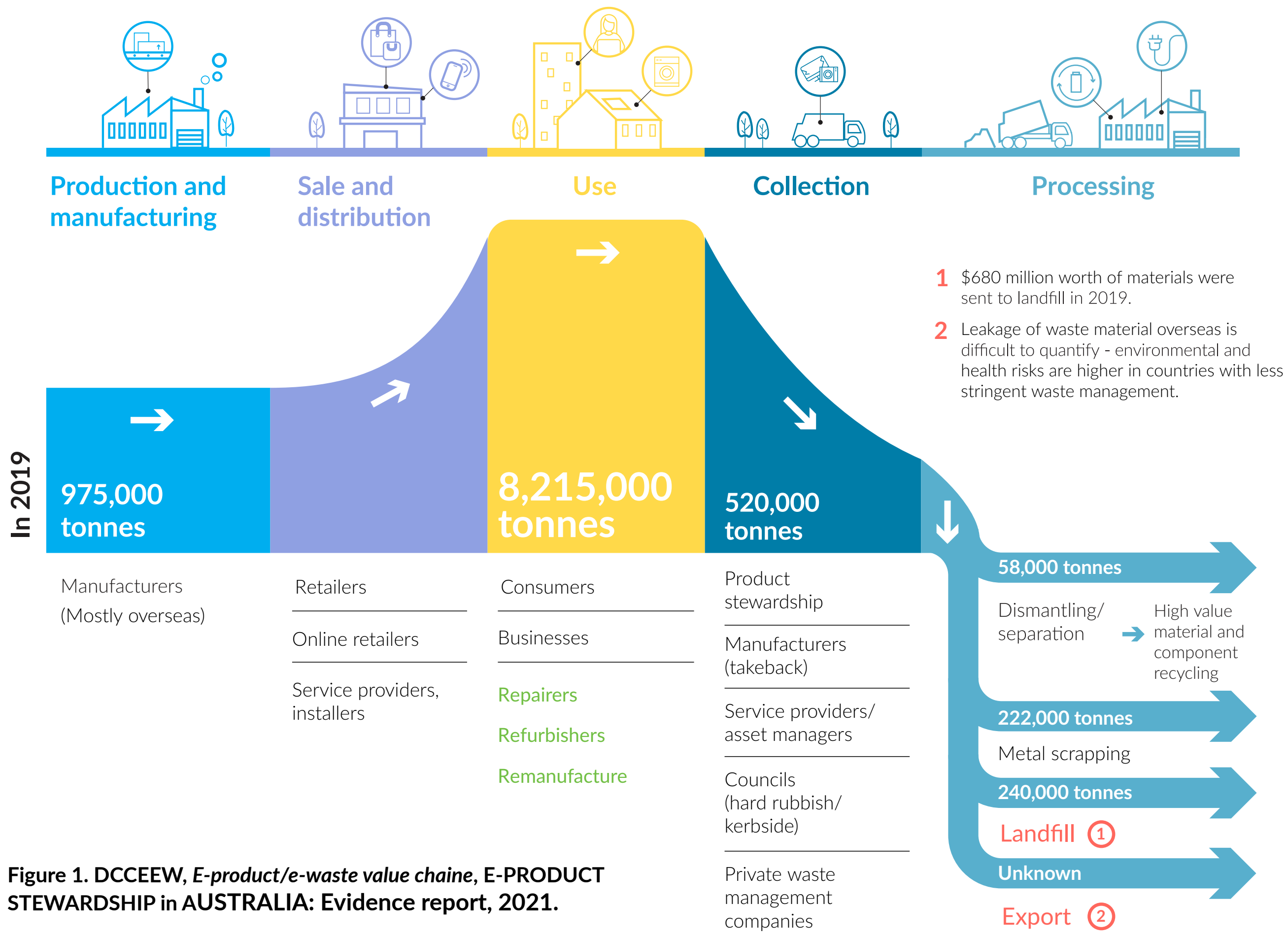


Figure 1. DCCEEW, *E-product/e-waste value chaine*, E-PRODUCT STEWARDSHIP in AUSTRALIA: Evidence report, 2021.

Our primary research into e-waste management began with an in-depth examination of the key sectors involved. We focused our efforts on understanding the processes and challenges within recycling centres and conducted several interviews with their staff to gather firsthand information.

One of the critical issues we discovered is the frequent occurrence of truck fires. These incidents are often caused by the improper disposal of e-waste in general waste bins, posing significant safety hazards.

Additionally, a survey we conducted with over 100 participants highlighted several key points:

- A widespread lack of awareness about proper e-waste recycling locations and procedures.
- Many people do not dispose of e-waste in the correct bins, contributing to improper handling and safety risks.

We also interviewed repair shop owners and found that many were not well-educated about proper e-waste disposal practices. This lack of knowledge further exacerbates the issue of incorrect disposal.

During our visits to recycling facilities, we uncovered further insights:

- A significant portion of e-waste is exported overseas.
- These facilities also sell some of the e-waste to various buyers, highlighting the complexities and economic aspects of e-waste management.
- This comprehensive approach allowed us to identify the main areas where intervention and increased awareness are needed to improve e-waste recycling practices and safety measures.

The widespread problem of inefficient recycling and lack of awareness on e-waste recycling.

The inefficient recycling system and the problems it poses (Islam et al., 2021):

1. Lack of Standardized Definitions and Regulations:

- Definition Ambiguities: There is no universally accepted definition of e-waste, making it challenging to categorize and manage appropriately.
- Inconsistent Regulations: Despite EU directives like RoHS and WEEE, only a third of e-waste in the EU is reported as collected and treated properly. A significant portion may end up in landfills or be illegally exported.

2. Collection and Sorting Challenges:

- Low Collection Rates: Consumer awareness about e-waste recycling is low, leading to poor collection rates. For instance, only 10% of mobile phones are collected for recycling in Germany.
- High Collection Costs: Collection and transportation incur significant costs, especially when extensive consumer awareness campaigns are required.
- Inconvenient Collection Methods: While kerbside and mail collection are convenient, they are also expensive. Accumulation of e-waste at collection points necessitates additional sorting efforts.

3. Technical and Economic Constraints:

- Recycling processes are less developed and less efficient compared to traditional recycling of bulk metals like aluminium or ferrous alloys.
- Complex Material Composition: Electronic devices are composed of a mix of materials that are difficult to separate. This complexity complicates the recycling process.
- Manual Disassembly Bottlenecks: Manual disassembly of complex electronics, which is often necessary to extract valuable or hazardous components, is labour-intensive and slows down the process.
- High Costs vs. Low Returns: While the recycling of metals like iron and aluminium is well-established, the recycling of electronic scrap remains costly due to the intricate separation processes required.

4. Informal Recycling Practices:

- Health and Environmental Risks: In developing countries, informal recycling methods often involve unsafe practices, leading to health and environmental hazards.
- Inefficient Resource Recovery: Informal recycling tends to focus on easily recoverable materials, leaving behind valuable resources that are lost.

5. Insufficient Data and Monitoring:

- Lack of Reliable Statistics: Precise data on the collection, recycling, and disposal of e-waste is often lacking, making it difficult to assess and improve recycling systems.
- Monitoring Gaps: Without robust monitoring and reporting systems, it is challenging to track the flow of e-waste and ensure it is being managed sustainably.

> **"50-80% of e-waste from developed countries is shipped to developing countries, often illegally."**
>
> **— Islam et al., 2021**

E-Waste Recycling Unawareness (Tanskanen, 2013):

One of the major barriers to effective e-waste management is the lack of consumer awareness about recycling. This issue manifests in several ways:

1. Unawareness of Recycling Programs and Locations:

Many consumers are unaware of where and how to dispose of their e-waste. For example, in Japan, a lack of knowledge about disposal options for waste personal computers has led to a significant stock of unused PCs in homes. This scenario is mirrored in Australia, where despite the availability of 1800 collection points under the National Television and Computer Recycling Scheme (NTCRS), many consumers still do not know how to utilize these services effectively.

2. Misunderstanding the Importance of E-Waste Recycling:

There is often a lack of understanding regarding the environmental impact of improper e-waste disposal and the value of materials that can be recovered. Consumers may not realize that e-waste contains hazardous substances that can harm the environment and human health if not properly managed. Additionally, valuable metals and materials are lost when e-waste is not recycled.

3. Behavioural Patterns:

Consumer behaviour towards e-waste is influenced by various factors, including consumption, disposal, storage, and recycling habits. A significant portion of e-waste is stored at home rather than being disposed of or recycled. Studies show that many electronic devices are kept in storage due to a lack of knowledge about disposal options or the perceived inconvenience of recycling.

4. Educational Gaps:

There is a need for targeted education and awareness campaigns to inform consumers about the benefits and processes of e-waste recycling. In Australia, for instance, despite initiatives like the NTCRS, there remains a significant opportunity to raise awareness and educate consumers on the appropriate disposal of e-waste.

> "In Australia, around 50% of mobile phones were kept in storage (not in use) between 2012 and 2014."
>
> — (Golev et al., 2016)

Importance of Consumer Awareness (Tanskanen, 2013):

The consumer plays a pivotal role in the initial phase of the e-waste recycling process. A positive attitude towards recycling is essential for the success of the entire system. Raising consumer awareness involves the following:

1. High Collection Rates:

Effective recycling depends on consumers understanding the ecological benefits and logistical feasibility of recycling. For instance, a study by Nokia found that globally, less than 10% of people recycle their old mobile phones. In industrialised countries like the US and the UK, only about 15% of consumers returned their obsolete phones for recycling (Tanskanen, 2013).

2. Information and Convenience:

Consumers appreciate clear information on how and where to recycle their e-waste. Successful collection programs rely on awareness, convenience, and longevity. Programs need to be in place for years to become a habitual practice for consumers (Tanskanen, 2013).

3. Collaborative Efforts:

Cooperation with various stakeholders, such as telecommunication operators, retail chains, recycling companies, and environmental NGOs, is crucial for creating efficient recycling systems. Educational initiatives and permanent take-back programs, like those offered by Nokia in almost 100 countries, are vital for increasing participation rates (Tanskanen, 2013).

> A study by Tanskanen's (2013) showed that, on average, individuals in Germany recycled 7.4 out of 11 common recyclable items, whereas in Indonesia, the average was only 1.4 items.

Addressing the unawareness of e-waste recycling is crucial for developing effective e-waste management systems. Enhancing consumer knowledge about the environmental impacts of e-waste and the benefits of recycling, coupled with clear information on available recycling programs, can significantly improve collection and recycling rates. Education and awareness campaigns tailored to specific demographic groups, such as young consumers, can play a pivotal role in shaping responsible e-waste disposal behaviours and promoting sustainable practices.

Image 1. Collage of images taken during primary research phase (taken at recycling facilities, e-waste drop-off locations, repair shops and other places visited).

2030 Onwards

Our vision of Australia from 2030 shows that technology advances and demands rise, and the production of electronic devices is projected to exceed current levels. Australia generated an estimated 650,000 tonnes of e-waste in 2021, which is projected to grow to 930,000 tonnes by 2035. This reflects a national increase of 2.6% annually (Sustainability Victoria, 2023). Victoria is expected to see a similar trend, with e-waste generation rising by 2.7% annually over the same period (Sustainability Victoria, 2023).

Australia's population is projected to reach 30 million by 2030 (Australian Bureau of Statistics, 2018). This population growth will lead to a higher consumption rate of electronic devices, consequently increasing the amount of e-waste generated. The dependency on technology in everyday life will also contribute to this rise; from personal assistant bots to automated vehicles, technology will be integral to daily routines. Virtual and augmented reality will become commonplace for communication and entertainment, further driving the demand for electronic devices. Additionally, with work, school, and social gatherings often conducted from home, face-to-face interactions will reduce, reinforcing the reliance on technology. Furthermore, there is a a growing lack of awareness about what constitutes e-waste and how to manage it properly. This lack of knowledge can lead to improper disposal practices, exacerbating the e-waste problem.

With the extensive amount of e-waste, it will start getting dumped on the footpaths of houses, and plastic will overflow out of garbage bins. The size of landfills would keep increasing, and with it no longer being able to fit the increased amount of waste, every suburb/ community would have its landfill. This situation will lead to contaminated air due to lead and other toxic contaminants in e-waste.

ABC NEWS (2022) also reported that the south-east side of Melbourne is running out of space. Mayor Anthony Marsh said, "We've got two to three years left, and there's one at Hallam that has four to five years left, and then we're done." At that point, in just five years, there will be no space in landfills across Melbourne's sprawling south-east, home to millions of people (ABC NEWS, 2022). Members of the community will fall sick with various respiratory diseases and chronic illnesses. The poisonous chemicals in the e-waste will then leach onto the soil and affect the quality of the soil. This will affect the quality of crops, and people will have to move to ways to produce and consume food at home.

With the expected increase in electronic devices, it will require manufacturers to secure more significant quantities of raw materials. However, extensive mining for these raw materials will lead to substantial environmental consequences, including increased landslides and potential geological disturbances. A vast quantity of water and energy is also required for the production. The world will have minimal energy and water consumption if government policies are implemented on how many resources every household can consume. A decrease in raw materials would lead to big manufacturers leaning towards using more plastic and unsustainable materials. This would increase the amount of non-recyclable plastics.

The Victorian government has also devised a plan for a circular economy called Recycling Victoria: A New Economy to look at innovative solutions for better recycling, reuse, and less waste (Victoria State Government, n.d.). This will help us to initiate a push for sustainable recycling methods for e-waste for the future of Australia. Government policies and regulations are crucial in shaping e-waste management in Australia. Stricter e-waste legislation, such as recycling mandates, disposal regulations, and extended producer responsibility (EPR) laws, are essential for effective management. Political stability ensures that these policies remain consistent, allowing for long-term planning and implementation. Additionally, funding and incentives, such as government subsidies, grants, and tax benefits for responsible e-waste disposal and recycling practices, will help provide necessary financial support and drive innovation in this sector.

As technology develops, the materials used in electronic devices become more complex, making it increasingly challenging for recyclers to process them properly. For example, unlike alkaline batteries, recycling lithium-ion (Li-ion) batteries is not straightforward due to their intricate chemical composition. Additionally, companies frequently release multiple versions of their existing products with only minor differences to maintain competitive advantage and drive revenue. This practice contributes to the growing volume of e-waste. These technological factors collectively exacerbate the challenges of managing e-waste effectively.

The increasing cost of living in Australia presents a significant economic challenge for e-waste management. In the last decade (2009-2019), the overall inflation rate, measured by the consumer price index (CPI), has increased 23.4 per cent (Parliament of Australia, n.d.). As living expenses rise, the affordability and availability of replacement parts for electronic devices will diminish, making repairs more costly and less feasible for consumers. This economic strain can lead to a higher rate of electronic device disposal rather than repair, thus contributing to the growing volume of e-waste. Additionally, the limited availability and high cost of parts not only affect consumer decisions but also place a financial burden on the economy, driving up costs associated with e-waste management and recycling efforts. To make matters worse, some manufacturers poorly label thier products, which will require more manual sorting and disassembly in factories further increasing the cost of recycling.

Legal factors significantly impact e-waste management in Australia. Copyright laws are increasingly being compromised, with tech companies copying each other without facing consequences to stay competitive and survive in the economy. This lack of enforcement can lead to a proliferation of low-quality electronic products, contributing to more e-waste. Additionally, the growing volume of e-waste might pressure some recyclers to resort to illegal actions to manage the surplus, such as improper disposal methods.

Ethical considerations play a critical role in e-waste management. Manufacturers are increasingly designing products with shorter life spans, typically lasting only a few years, which encourages frequent replacements and contributes to more e-waste. When the team conducted an interview with a repair store, we discovered a trend in the repair difficulties among variations of the same electronic devices. For example, the iPhone 4 and 4s series were hard to repair, while the iPhone 6 series was easier. Then, the iPhone X was difficult again, but the iPhone 14 Pro and Pro Max were easier to repair. This up-and-down trend also affects business, as the high labor costs for difficult repairs often lead people to opt for a new phone instead. Additionally, the prices of phones and other electronics are often inflated, not reflecting their true value, especially between different series of the same model. This practice exploits consumers and promotes a cycle of overconsumption. Furthermore, manufacturers have made it increasingly difficult to repair products, leading to the decline of repair shops. As a result, consumers are forced to buy new products instead of repairing existing ones, further increasing e-waste and negatively impacting local repair businesses. Addressing these ethical issues is essential for fostering sustainable consumption and reducing e-waste.

The BLOOM Project

Introducing the BLOOM Project, a solution aimed to turn today's e-waste into tomorrow's technology. The BLOOM Project is a two-part solution that creates a new way for sustainable recycling (through BREW) and helps to spread awareness about e-waste and its impact on the community (through BLOOM Hubs). It will be placed in surrounding gardens/parks, starting with Melbourne Royal Botanical Garden, in the city and over time aimed to spread across Australia.

With BLOOM Hubs and BREW located in surrounding gardens and parks, we hope to encourage the public to step out of their homes and enjoy a walk in the park as a form of exercise as well.

BREW

Introducing Brew

BREW (Bio-Reactor for E-Waste Recycling) is a large industrial-scale bioreactor that is 9 meters tall and 4 meters wide, designed specifically for recycling e-waste and recovering metals within them. It utilises the capabilities of certain microorganisms to recover metals from e-waste, through a process known as bioleaching.

The main focus of BREW is to ensure that even secondary e-waste components, which are usually exported overseas, are recovered within Australia and that this recycling process is done in an environmentally friendly and sustainable manner.

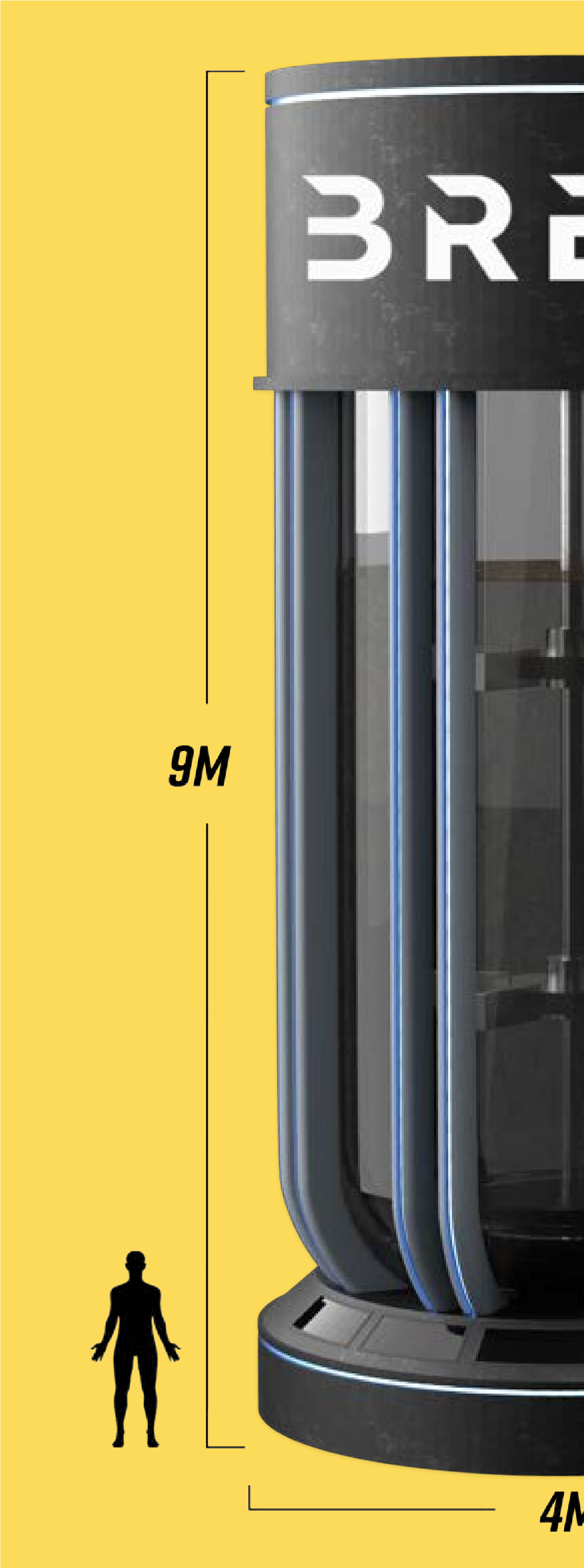
Understanding the Basics

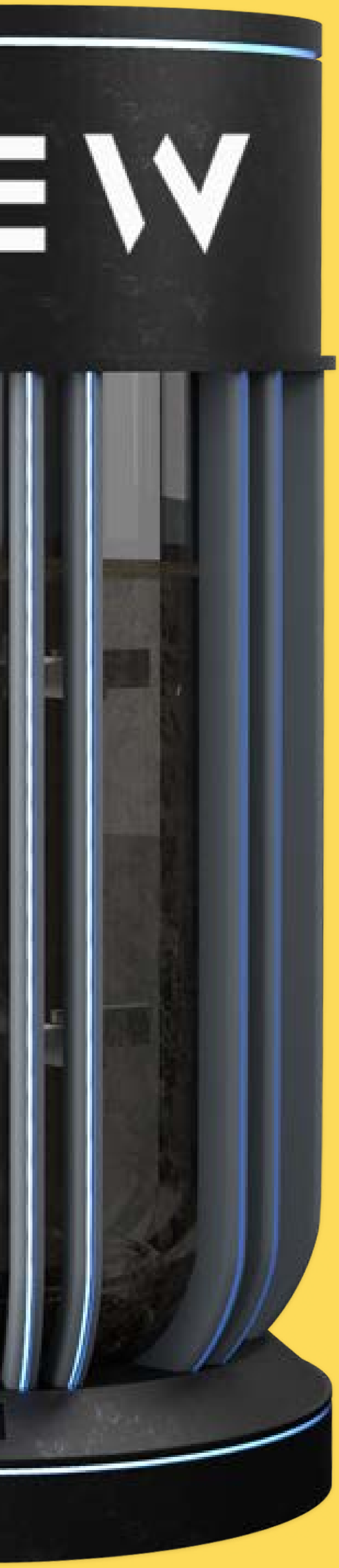
To understand BREW's recycling process, we need to understand what Bioleaching is and how it works.

Bioleaching is a process that utilises the ability of microorganisms (or microbs) such as bacteria, fungi, and archaea to produce acids, oxidise metals, or secrete chelating agents to dissolve and mobilise metals from ores, offering a greener alternative to conventional methods of metal extraction. Bioleaching is considered a low-power-consuming, highly efficient, environmentally friendly and cost-effective process that can be carried out at room temperature and atmospheric pressure, providing the specificity to target and recover high-purity metals effectively and cost-efficiently from low-grade ores. This technology presents a sustainable solution for recovering valuable metals from electronic waste (e-waste) *(Bhat, Cui, Ameen, Li & Kumar 2023).*

Despite its advantages, bioleaching faces challenges such as slower processing times, the need for optimal microbial and environmental conditions.

BREW helps in reducing these disadvantages by utilising Hylight technology, and over the years, improves the efficiency of the bioleaching process.



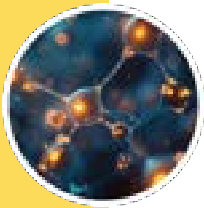


The Process

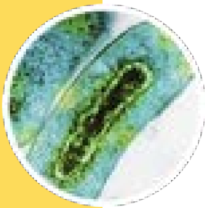
Recyclers provide BLOOM with e-waste that underwent a series of preparatory steps including crushing, shredding, milling, and passing through screening processes such as an eddy current system. This e-waste powder is added into BREW.

Depending on the targeted metal, a selected microbial culture is introduced along with the e-waste into BREW.

Water is added to create an aqueous medium, which facilitates the bioleaching process. Nutrients and oxidizing agents are also added to ensure a healthy microbial population density and to enhance recovery efficiency.



Microorganisms then interact with the e-waste, producing acids and other compounds that help dissolve the metal into the solution.



Hylight technology analyzes and monitors the microbial culture, ensuring that the environment within BREW remains optimal based on the microorganisms' metabolic profile. Additionally, Hylight aids in identifying new strains of microorganisms capable of high rates of metal recovery.

Once the leaching process is complete, the leachate solution is collected for further processing.

Metals are recovered in solid form through processes such as electrowinning, which is based on the principles of electrolysis.

Finally, the recovered metals are prepared to be sold to manufacturers and other stakeholders.

Hylight Technology

The HYLIGHT project, funded by the European Union's ATTRACT program, a revolutionary diagnostic device to enhance embryo selection in in vitro fertilization (IVF) procedures.

HYLIGHT proposes a non-invasive method to classify embryos based on their metabolic profile. It utilises the intrinsic fluorescence of key molecules within the embryo to image them in a natural state. This approach overcomes limitations of existing technologies like time-lapse monitoring and genetic testing.

A key component of HYLIGHT is hyperspectral imaging, a powerful technique that analyzes a wider range of light wavelengths compared to traditional color imaging. This allows for a more detailed assessment of the embryo's metabolic health. The proof-of-concept device that's been built combines light-sheet microscopy, multiphoton imaging, and a novel hyperspectral phasor analysis powered by artificial intelligence (AI) (ATTRACT, n.d.).

This breakthrough technology overcomes the classical limitations of hyperspectral imaging applied to biological samples, namely speed, phototoxicity, and resolution.

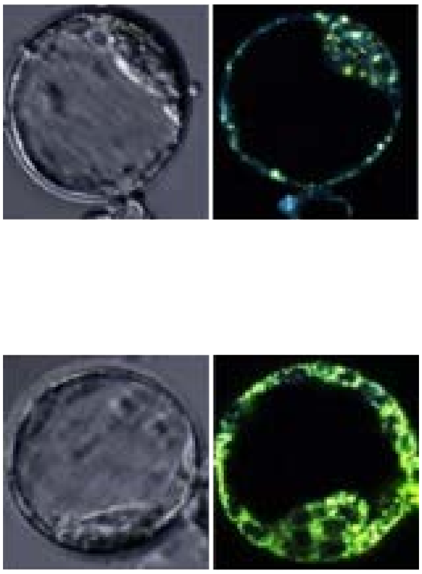


Image 2. IBEC, *Image of a control (two left panels) and a metabolically stressed embryo (two right panels)*, IBEC Institutional News, July 20, 2022.

Techniques Used

Light-Sheet Microscopy: This technique illuminates the embryo with a thin sheet of light, allowing researchers to capture high-resolution images of its internal structures without harming the embryo. Imagine shining a spotlight through a slice of the embryo to see its details in that specific layer.

Multiphoton Imaging: This technique uses special lasers to excite multiple photons within the embryo simultaneously. This deeper light penetration allows imaging of structures further within the embryo compared to traditional microscopy techniques. It provides more information about the embryo's internal composition.

Hyperspectral Phasor Analysis: This technique analyses the fluorescence emitted by various molecules within the embryo across a broad range of wavelengths of light. By analysing this detailed spectral signature, researchers can gain insights into the types of molecules present and even their activity levels within the embryo.

AI-powered Analysis: The use of AI allows for automated analysis of the vast amount of data collected. AI algorithms can identify subtle patterns in the data that may be difficult for humans to detect, leading to more accurate embryo selection.

Purpose of Hylight in BREW

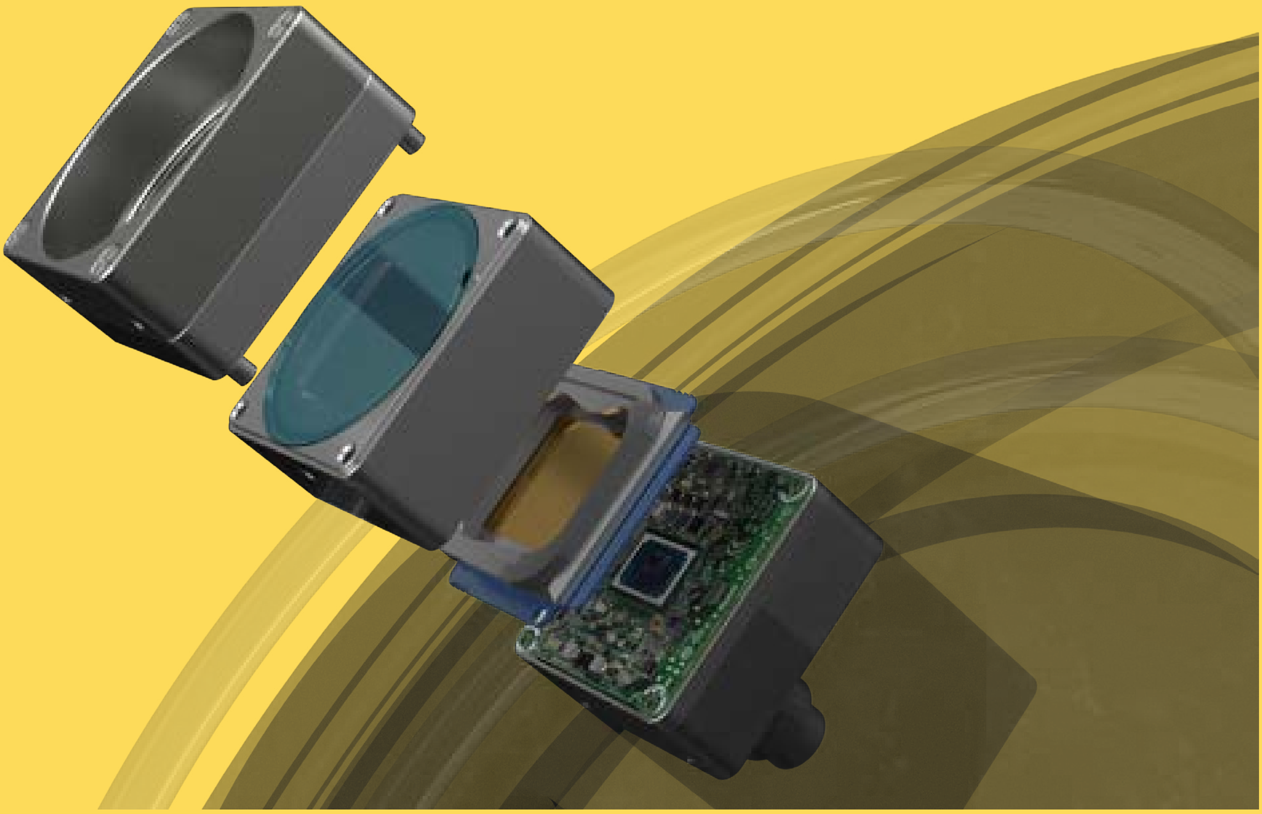
Hylight plays a pivotal role in optimizing the BREW system for efficient bioleaching of e-waste. This technology enhances the system's ability to handle and process electronic waste by leveraging sophisticated monitoring and automated controls to foster an ideal environment for microbial activity and analyse microorganisms to identify mutations, which could lead to the discovery of new, more efficient microbial strains.

One of the key features of Hylight within the BREW system is its ability to automatically collect and analyse samples directly from the bioreactor. This automation reduces the need for manual sampling and laboratory analysis, significantly speeding up the feedback loop and allowing for rapid adjustments to the leaching process.

In BREW, Hylight is primarily tasked to analysing the metabolic profiles of the microorganisms used in the bioleaching process while providing the BREW system critical real-time data to adjust environmental parameters dynamically. This ensures that the conditions within the reactor—such as pH, temperature, nutrient levels, and oxygen—are continually modified to create the most conducive environment for the growth and activity of bioleaching microbes. This dynamic adjustment is crucial because the microbial metabolism directly influences the leaching efficiency, with different strains of microorganism requiring specific conditions to optimise its metal recovery capabilities.

Furthermore, by monitoring these metabolic profiles of the microorganisms used in the bioleaching process, Hylight can determine the health and efficiency of the microbial population, ensuring that only the most effective bioleaching activities take place. This analysis helps in identifying any deviations from expected metabolic activities, which can signify the presence of mutant strains or suboptimal leaching conditions.

By integrating these functionalities, Hylight not only boosts the efficiency and output of the bioleaching process but also enhances the overall sustainability of metal recovery from e-waste. This reduces environmental impact and resource wastage, making it a valuable tool in the pursuit of greener and more sustainable waste recycling technologies. Through precise control and monitoring, Hylight ensures that BREW operates at peak performance, maximizing metal recovery while minimizing costs and environmental footprint.



BLOOM EXPERIENCE HUBS

Introducing Brew

Bloom is an experience hub that consists of four distinct pods around BREW. It aims to raise public awareness about e-waste and its impact. Designed as a place where the public can visit, learn, and drop off their unwanted e-waste, Bloom provides a comprehensive educational and recycling experience. It is estimated to be 36 metres in diameter and stand 9.6metres tall.

Augmented Reality (AR) & Hologram Pod

This pod uses AR technology, allowing visitors to see what's inside everyday electronic products (see Image 6 in Appendix). It shows exploded views and detailed information about the materials used. This feature provides fascinating insights into the composition of electronics and the importance of recycling, enhancing public understanding and encouraging more responsible e-waste management practices.

Additionally, holograhic image projections help visitors understand the intricate workings of BREW. Through interactive displays, visitors can explore processes such as bioleaching and the recycling system, which includes the collection, sorting, and crushing of e-waste before it is sent to BREW. This immersive experience educates the public on BREW's operations, fostering greater appreciation and support for responsible e-waste recycling.

Image 2. Public learning about the BREW recycling process through interactive holographic display at AR/Holographic .

Virtual Reality (VR) Pod

One of the distinct pods in the BLOOM experience hub is the Virtual Reality (VR) Pod. This pod features individual VR stations where users can immerse themselves in a virtual world to explore the impact of e-waste both in Australia and globally. Through this interactive experience, visitors will gain a deeper understanding of the environmental and health consequences of improper e-waste disposal. Additionally, the VR Pod offers e-waste-related games, allowing users to engage with the topic in an educational and entertaining way. This immersive approach not only informs but also motivates individuals to adopt more responsible e-waste management practices.

Image 3. Virtual Reality Hub

Drop Off & Information Pod

This pod provides convenient drop-off points for old e-waste, where visitors can responsibly dispose of their unwanted electronic devices. Alongside the drop-off points, the pod offers quick summaries and statistics about e-waste, educating visitors on the scale and impact of the issue. By combining practical disposal solutions with informative content, the pod encourages visitors to not only drop off their e-waste but also to leave with valuable knowledge about e-waste management and its environmental significance. This dual approach fosters a more informed and engaged community, promoting sustainable practices and greater awareness.

Image 4. Drop-off and Information Hub

Recreational Pod

The Recreational Pod in the BLOOM experience hub is designed as a versatile, transformable space that can flexibly be turned into pop-up stores or event spaces. This adaptability allows for a variety of activities, from community events and workshops to temporary retail spaces, all aimed at drawing more people to BLOOM. By attracting a diverse audience, the Recreational Pod not only enhances visitor engagement but also spreads awareness about BLOOM and its mission. This increased foot traffic helps to promote the hub's educational and environmental initiatives, fostering a greater understanding and commitment to responsible e-waste management among the public.

Image 5. Recreational Hub

Roadmap

2025

- Research and development on BLOOM experience begins
- Development in augmented and virtual reality technologies
- Development in Hylight technology allows Hylight to classify microbes on their metabolic profile
- Government funded incentive programs for proper e-waste disposal

2030

- Installation of BLOOM experience hub
- E-waste Education Grants (Round 2) by Sustainability Victoria
- Hylight technology analyse different strains of microbials and identify the most efficient strains with the help of advanced AI technology
- Development in holographic technologies

2035

- BREW installation and trial phase begins
- E-waste Infrastructure Grants (Round 3) by Sustainability Victoria
- Development in HYLIGHTS technology to make it small and compact for easy intergration into brew system leading to brews first installation and trial

2040

- Introducing BREW to be adapted by councils and recycling facilities
- BREW achieves high efficiency rate with minimal running cost & carbon foot

2050

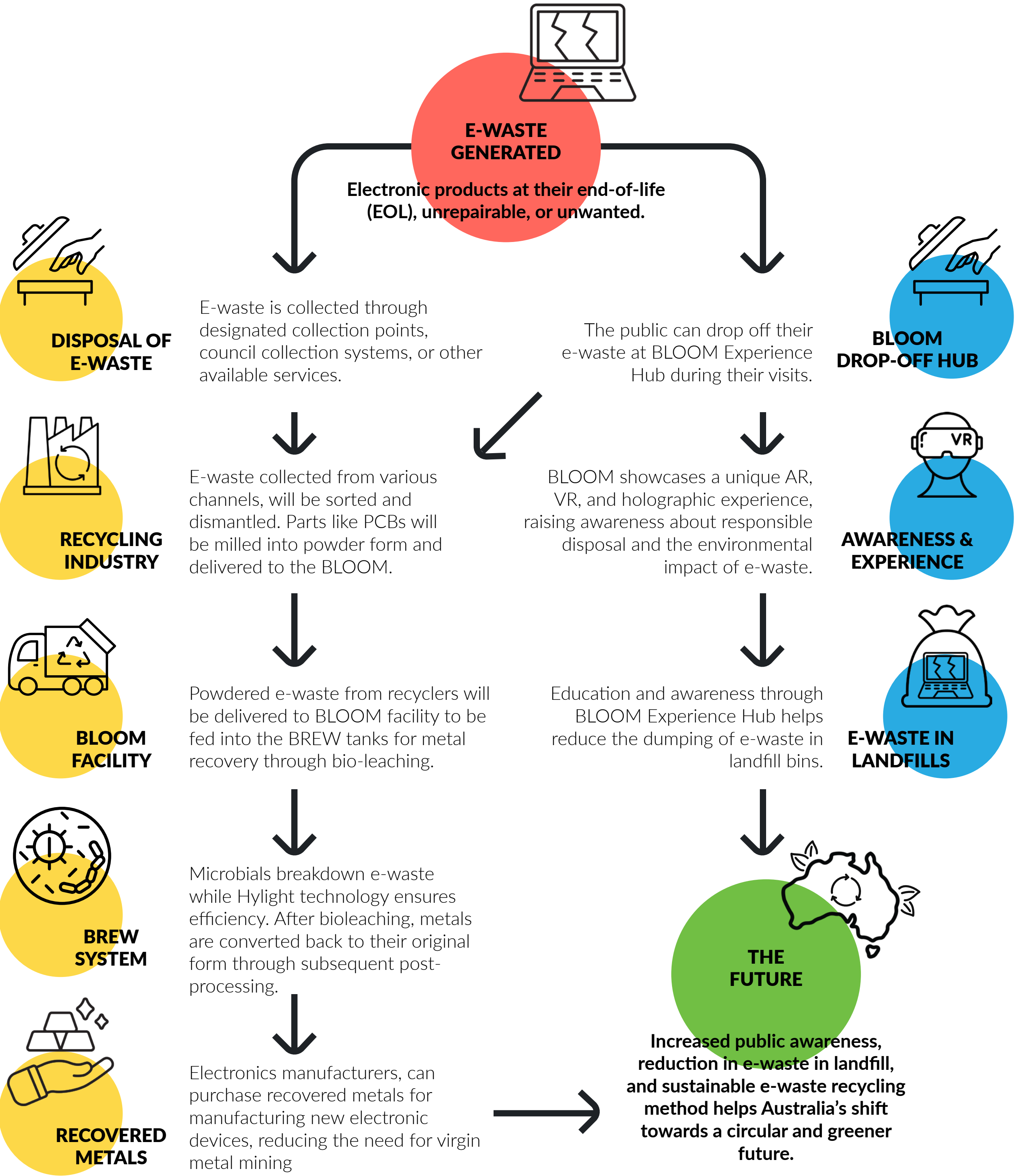
- BLOOM experience hub is now spread all across Australia

SOLUTION

TECHNOLOGY

Flow of E-Waste

This proposed system map, utilising BLOOM Experience Hubs and BREW, will promote a circular and greener economy while increasing public awareness, for an ideal future. This proposal also helps to divert e-waste components that are usually exported offshore to be processed within Australia and the recovered materials can be used to produce new electronic products. The public (consumers) and other stakeholders will have a better understanding of the e-waste recycling process with BREW and be more inclined to participate in the system, contributing to a sustainable future in Australia.



Value Proposition

Increased Public Awareness

- Educational Impact: Exhibition pods in city gardens will attract a diverse audience, providing education on e-waste issues and sustainable recycling practices. Interactive and visually engaging displays will foster a sense of involvement and responsibility among citizens.

Zero Landfills

- Waste Reduction: Efficient recycling processes like bioleaching and high recovery rates of valuable metals will significantly reduce the volume of e-waste sent to landfills.

- Sustainable Practices: The focus on bioleaching promotes sustainable recycling practices, reducing environmental impact.

No More Mining

- Resource Conservation: By recovering valuable metals from e-waste through bioleaching, the need for new mining operations is minimized, preserving natural resources and reducing ecological damage.

- Economic Benefits: Recovery of metals from e-waste recycling is often cheaper and less environmentally damaging than traditional mining, providing economic incentives for recycling.

Material Recovery

- High recovery rates of metals through bioleaching ensure that valuable resources are reused in the manufacturing of new products.

Circular Economy

- The proposed system supports a circular economy by keeping materials in use for as long as possible, reducing waste, and promoting the continual use of resources.

Conclusion

The integration of bioleaching tanks coupled with public education through exhibition pods in city gardens, presents a comprehensive solution to the inefficiencies in current e-waste recycling practices. This approach not only enhances the recovery of valuable materials but also fosters public awareness and engagement, driving the transition towards a sustainable and circular economy. By implementing this system, we can achieve significant environmental benefits, reduce reliance on landfills and mining, and promote a more efficient recycling process.

Future Steps

To shape the future of Bloom and Brew by involving key stakeholders and expanding into the market of raw materials extraction and selling, here is a detailed strategy that includes stakeholder involvement and business expansion into raw materials:

Government Involvement

Advocate for policies that support the use of recycled raw materials in manufacturing.

More regulations in place for recycling e-waste and regulations placed on companies and manufacturers.

Ensure compliance with local and international environmental trade regulations.

Expanding Raw Material Sales

Form partnerships with electronic manufacturers and producers to supply them with high-quality recycled raw materials.

Explore opportunities to export these materials to international markets, reducing the global dependence on mined raw materials.

Sustainable Business Model

Implement a circular economy model where materials are continually reused, reducing waste and environmental impact.

Ensure all business practices align with sustainability goals, from sourcing to production to distribution.

Implementation Strategy

Continuously assess the progress and adapt strategies as necessary based on market demands and stakeholder feedback.

Establish channels for stakeholders to provide input and suggestions.

Monitoring and Evaluation

Track reductions in mining activities and increases in the use of recycled materials and this will be a beneficial statistic for implementing strict strategies on recycling.

Track reductions in mining activities and increases in the use of recycled materials.

Publish annual reports detailing the environmental and economic impact of the recycling and raw material sales initiatives.

Conduct quarterly reviews to ensure objectives are being met and to make necessary adjustments.

Modular and Portable Systems

The challenges posed during this idea included the lack of modularity and portability. In the future including creating tanks in different sizes that can be interconnected will allow for scaling up or down based on the volume of e-waste to be processed.

By developing a modular, portable, and scalable bioleaching system, we can create a versatile solution for e-waste recycling that can be deployed anywhere in the world. This approach allows for the efficient recovery of valuable metals from e-waste, supports sustainable recycling practices, and can adapt to the varying needs of different regions and scales of operation.

Designing smaller, mobile BREW units that can be transported via trucks or containers. These units could handle smaller amounts of e-waste and be deployed quickly to areas with temporary high e-waste output.

Establish BREW recycling centres in areas with large accumulations of e-waste, such as during electronics fairs, in urban centres, or in developing regions experiencing a surge in e-waste.

To cater to different scales of e-waste recycling, the system can be developed in varying sizes:

Small-Scale Units:

- Suitable for local recycling centers, small communities, or even individual businesses.
- Can process a few tons of e-waste per month.
- Portable and easy to set up.

Medium-Scale Units:

- Ideal for city-level recycling programs or medium-sized industrial applications.
- Capable of handling tens of tons of e-waste per month.
- Modular design allows for expansion.

Large-Scale Units:

- Designed for industrial-scale operations or national recycling programs.
- Can process hundreds of tons of e-waste per month.
- Integrated with advanced recovery and purification systems.

Meet the Team

Nikhail Ram Sharma *(UI/UX Designer)*

https://www.linkedin.com/in/nikhailramsharma/

The CBI A3 project has pushed me out of my comfort zone of practical thinking and challenged me to embrace radical ideas as we developed our solution. I never imagined myself researching and devising a solution for the future towards 2050. This project has also made me more conscious of sustainability and our impact on the environment. I have learned various ways to present impacts or problems to people, which is crucial in the field of user experience design, where it is essential to illustrate "Why is there an issue?", and how the proposed solution addresses it. Lastly, working in teams with people from different backgrounds has taught me the importance of communication for the success of the project. A project I will remember for life.

Amisha Thottupurkal *(Interior Designer)*

As an interior designer pursuing my master's in design at Swinburne, this 9-month project has been an exhilarating journey filled with numerous lessons. I had the opportunity to meet and collaborate with students, designers, engineers, and teachers from around the world, which has been incredibly enriching. This experience has significantly enhanced my soft skills, such as teamwork and collaboration, and increased my hard skills, making me a more proficient and effective designer.

Anoop Ebby Kurien *(Visual Artist/Interior Designer)*

The opportunity provided by the CBI A3 project allowed me to grow immensely, both personally and professionally. As an interior designer, the project not only pushed me out of my comfort zone but also enabled me to explore other design landscapes. The most valuable aspects of the project were meeting and collaborating with people from other disciplines, as well as the CERN experience. Every day of the 9-month journey was a learning experience, from understanding environmental and societal problems to examining them from multiple angles to narrow down and find solutions using technology. One of the key lessons I learned was the importance of looking further into the future and imagining the benefits our solutions could have.

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Appendix

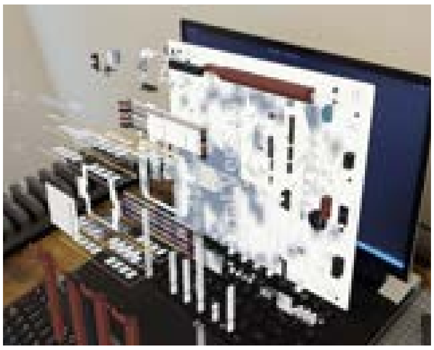


Image 6. Prototype test - Exploded view of a motherboard in AR

Snapshots from Project Showcase

Previous Ideas & Prototype

Prototype 1- Smart Interactive Glasses

Aimed at targeting users, mainly consumers who are unaware of what to do with their e-waste, we incorporated augmented reality where users can scan their e-waste and receive feedback through their glasses. This feedback will include information on where to recycle, repair costs, additional details, and some statistics on e-waste.

Prototype 2- Smart Bins

Aimed at targeting consumers who are unaware of how to recycle their e-waste, this system uses a scanner to help users identify and properly dispose of their old e-waste. Users can scan their e-waste, and the scanner will determine its type and open the respective bin for disposal. The e-waste bins are colour-coded and equipped with lights to guide users on where to throw their e-waste. Additionally, important information is available for users to read and learn more about the type of e-waste and its environmental impact.

Prototype 3- Separation & Battery Locator in Recycling Facilities

This idea focuses on improving recycling facilities' processes to locate batteries in e-waste and prevent contamination of other clean parts. Upon visiting and interviewing several recycling collection centres and a recycling facility, we discovered that batteries in some products, like toys, etc., are hard to detect. Locating them takes a lot of time, and if they are not found and end up in clean areas, the batteries may explode and cause fires. As a result, we decided to develop a machine that detects and separates e-waste products based on whether they contain batteries. Using augmented reality, workers will be able to locate the batteries in the e-waste and receive prompts on the tools needed to remove them safely.

Prototype 4- Drone & Smart Collection System

To avoid e-waste from ending up in landfills, the team decided to examine the collection system in Melbourne. We considered incorporating a drone into waste collection trucks. The drone would fly around collecting e-waste from houses and bring it back to the trucks. Inside the truck, an artificial intelligence camera would detect the e-waste and sort it into the appropriate bins. For general bins, the AI camera would sense if they contain e-waste and inform the workers to remove it.

Phrase 1 Idea (REME, MEME & RecycleMe)

The team focusing on improving consumers' recycling habits and consumption behaviour with a 3-step solution: REME, MIMI, and RecycleME, addressing over-consumption of electronic devices, data/privacy concerns, and collection management.

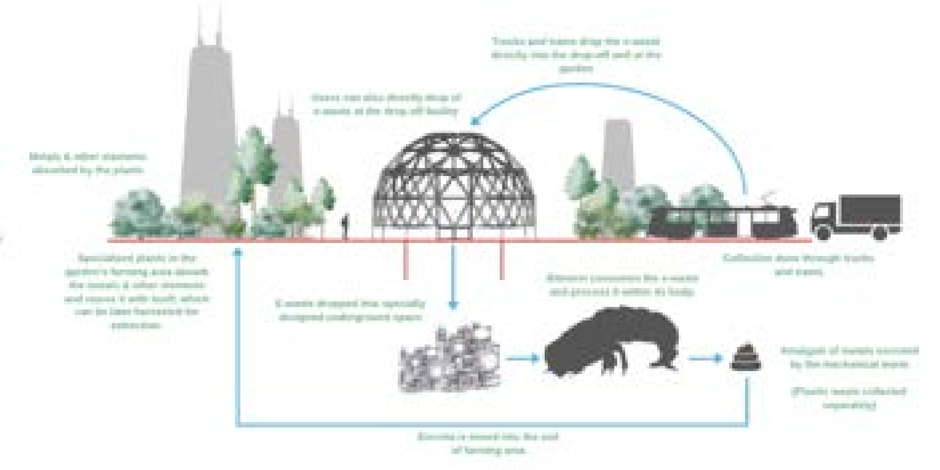
REME: REME is a container pod placed around Melbourne for automated, free e-waste collection. It uses a robotic arm to pick up, scan, and diagnose e-waste, providing repair reports. If repair is not possible, it erases data in front of users and sorts the items by type.

MIMI: MIMI is a miniature robot located in public spaces like city councils and libraries. Using AI, it interacts with consumers, educating them about e-waste through statistics and videos.

RecycleME: RecycleME is a web and mobile application system connecting councils and consumers. It standardises the recycling system across Melbourne, providing a platform for announcements, updates, forums, and notifications, helping consumers plan e-waste recycling and access information and statistics.

Solution Concept from Design Detail Presentaion (E-GREEN Communal Garden + Bitworm)

The team developed a solution for an E-Green communal garden, focusing on collecting and recycling e-waste. This garden allows consumers to visit, drop off their e-waste, and observe the recycling process, which operates underground.



For the collection of e-waste, the team proposed using Melbourne trams and trucks. An additional cabin would be attached to the back of trams for consumers to deposit their old e-waste. A new tram stop would be opened at the communal garden, where the e-waste would be dropped off underground for processing.

Regarding the recycling of e-waste, once it is dropped off at the E-Green Communal Garden, each Bitworm, designed to consume a specific type of e-waste, utilizes advanced technologies such as VISIR2 and AI to identify its assigned e-waste. Equipped with a powerful shredder in its mouth, the Bitworm dismantles and breaks down the e-waste into smaller pieces. These pieces are then moved into the abdominal part of the worm, where further breakdown occurs. In the abdomen, genetically modified microorganisms continue the decomposition process. Using HYLIGHT technology, the activity of these microorganisms is monitored. The end product is a paste amalgam of various metals. Genetically modified hyperaccumulator plants, using phytomining, absorb these metals, allowing for their recovery.