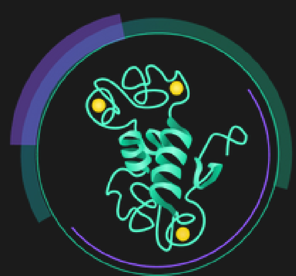
NEOCYCLE

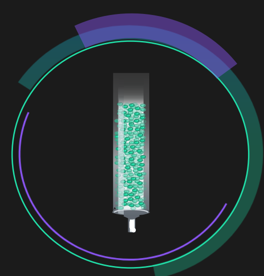
Rare earth elements (REEs) are ubiquitous in our day-to-day lives, essential in many modern technologies from the circuit boards in our personal laptops, to the catalytic converters in our cars, trains and buses. As the demand for REEs is expected double by 2026, it is apparent that the current supply chain is unable to meet global demands. NEOCYCLE aims to utilize electronic waste, a massively untapped source of REEs, to develop a novel and sustainable synthetic biology approach for circular REE extraction, recovery, and usage.

E-waste is repurposed as a **SUSTAINABLE** REE-source

Lanmodulin, a metal-specific protein, **BINDS REES**



Our lanmodulin-based system **RECOVERS REEs** from e-waste leachate

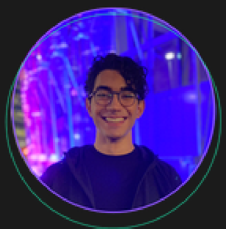


REEs are then used in new technologies for a **CIRCULAR ECONOMY**

2021

- **Begin REEcovery prototype development**
- **File for patents & secure IP**
- **Launch pilot program**
- **Nationwide Adoption**
- **Develop international collaborations**

2026



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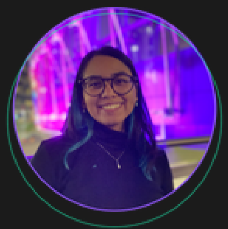

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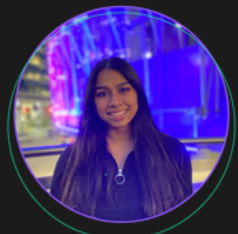

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We live in an age of technology, where **rare earth elements (REEs)** play significant roles in your laptops, cellphones, and automobiles. However, we face a looming threat of REE scarcity as demand for REEs exceed supply by around 3,000 tons annually — that is nearly 20 Statues of Liberty per year! The effects of REE scarcity will be felt worldwide, resulting in an immediate need for a sustainable, accessible, and cost-effective source of REEs.

RARE EARTH ELEMENTS

REEs are a series of 17 elements, 15 of which are from the lanthanide group. While these elements are abundant in the earth's crust, they are typically found in vein-like ore deposits, making them energy-intensive and expensive to extract through conventional mining methods. Furthermore, 90% of the global REE supply is controlled by China, resulting in a near monopoly of an already relatively inaccessible resource.

21	39	
Sc	Y	
Scandium	Yttrium	
44.956	88.906	

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Lanthanum	Lanthanum	Thulium	Ytterbium	Lutetium
138. 905	140.116	140.908	144.240	144.913	150.4	151.964	157.2	158.925	162.500	138. 90547	138. 90547	168.934	173.05	174.967

CURRENT METHODS

Currently, REE extraction is primarily done through ore mining, which involves environmentally harmful and radioactive materials, such as strong acids and organic solvents. Furthermore, this process is time-consuming and expensive. When REEs are recycled, it is done so using processes such as hydro- and pyrometallurgy, both of which are also detrimental to the environment. On the other hand, e-waste recycling facilities already exist, but tend to prioritize materials such as steel, plastics, and precious metals. As such, the growing REE demand can be met by implementing sustainable REE extraction processes into already existent e-waste recycling facilities.

E-WASTE

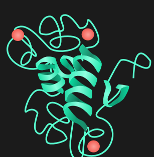
Electronic waste is the fastest growing solid waste stream, with over 54 million tonnes produced annually. That's heavier than over **2000 Empire State buildings!** Of this massive amount, only 17% is properly recycled through formal e-waste management infrastructure. Due to the technical complexity of REE recycling, they are some of the hardest materials to recover from e-waste, with less than 1% being recycled annually. This results in over 47 billion dollars' worth of raw materials lost every year. Although current e-waste recycling processes exist, they lack the technology required to sustainably isolate REEs from the stream for future use. As e-waste contains a large amount of these metals, it is an ideal alternate source of REEs.

Neocycle is a human-centered project that aiming to address industry needs by continuous stakeholder consultation and feedback while stimulating local economies by helping provide decent and equitable livelihoods. According to **Dr. Huy Dang**, a professor at Trent University's School of Environment, current extraction methods are harmful, and our approach provides a promising and sustainable alternative. Given the risks posed and complexity of current methods, Neocycle presents a potential alternative towards the first step towards a circular economy.

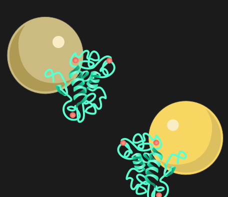
REE-COVERY TECHNOLOGY

Current methods utilized by the industry are costly, energy-intensive, and lack selectivity. Our system utilizes **lanmodulin**, a highly-selective REE-binding protein, allowing us to develop our **REE-covery technology.**

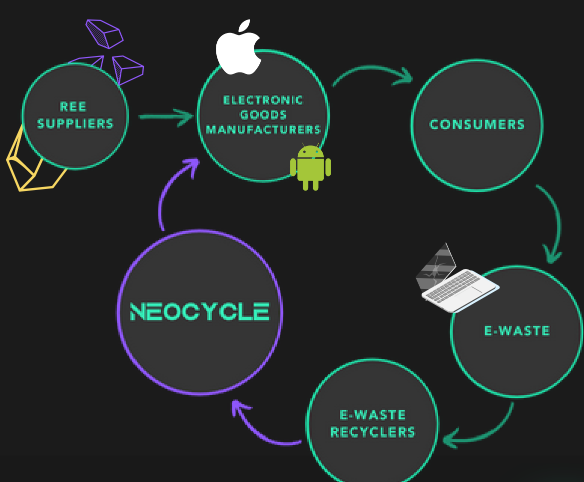
Our solution is to be implemented into pre-existing recycling facilities, where e-waste is already dismantled and processed. Based on our meetings with two e-waste recycling facilities, E-Cycle Solutions, and Quantum Lifecycle, Neocycle would fit seamlessly into their current recycling pipeline. Neocycle is only one step in the long line of processing, where precious resources are extracted from e-waste solubilized by acids. This solubilized waste will be passed through the REE-cover system for REE extraction and collection.



In order to efficiently recover e-waste, we needed an accessible hardware design. Our REE-cover column includes the lanmodulin protein stuck to cellulose beads. Think of the cellulose and the column like velcro - since lanmodulin can't stick directly to the column without having issues in effectiveness, we placed it on a cellulose bead instead.



Once we pour our solubilized e-waste through the column, the lanmodulin-cellulose complex will hold on to the REEs while letting everything else pass through. Once the column is clear of the unwanted aspects of the e-waste solution, we will add citrate, which causes the release of REEs by lanmodulin. This REE-citrate solution can then be collected, oxidized, and then sold back to electric goods manufacturers.



NEOCYCLE closes the loop on the REE supply.

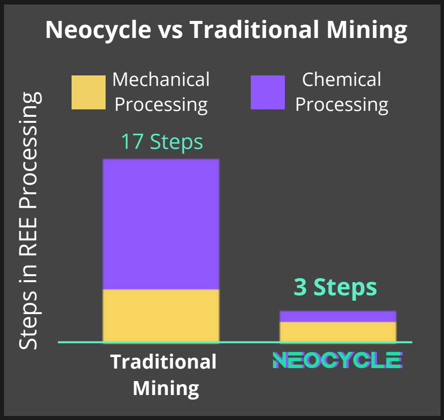
Finally, these products penetrate the public sphere as consumer electronics that, after a finite lifespan, will end up as electronic waste that serves as a feedstock for the REE-cover process all over again. Thus, creating a circular supply line for REEs.

Currently, REEs are sourced through mining: an environmentally harmful, time-consuming, and expensive process. In rare cases where REEs are recycled, it is done using processes such as hydro- and pyrometallurgy, both of which release toxic byproducts. These methods also require complex chemical steps, resulting in poor working conditions.

This is where our solution comes into play. NEOCYCLE has numerous competitive advantages over conventional REE recovery, enabling our customers to get extra value out of their waste processing. It is safer, energy-efficient, and more eco-friendly, all while maintaining a similar recovery rate. By providing a viable, long-term solution to the REE scarcity problem, Neocycle promotes the formation of a circular economy, where end-of-life products are repurposed as a new source of precious materials.

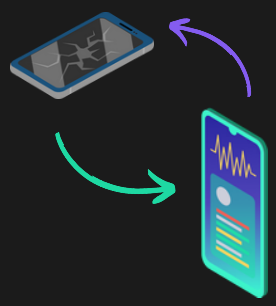
ENVIRONMENTAL IMPACT

Currently, over 2.7 tonnes of raw ore is required to produce just 1 kg of Neodymium (REEs), which then produces 247 kg of CO2. This is an energy-intensive complex process, consisting of many steps of physical and chemical separation. Neocycle's biology-based REE-cover system capture REEs from a much more sustainable source, bypassing environmentally damaging mining practices. Unlike traditional mining, by manually isolating e-waste components high in specific elements, the REE-cover system can produce a consistent concentration of certain REEs. This process enables a more predictable output of specific REEs with less operational complexity.



ECONOMIC IMPACT AND HUMAN CENTERED DESIGN

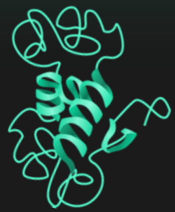
Neocycle creates an economically feasible and domestically stable source of REEs while providing high quality jobs and protecting local economies. We strive to raise awareness about the rampant NIMBY-ism (Not In My Backyard) in Canada resulting in the absence of an e-waste problem within our borders at the expense of those in the Global South through illegal e-waste shipments. Neocycle enables any country to leverage its local electronic waste as a sustainable source of REEs, thereby increasing domestic market supplies and challenging the existing global monopoly on REEs.



RISK ANALYSIS

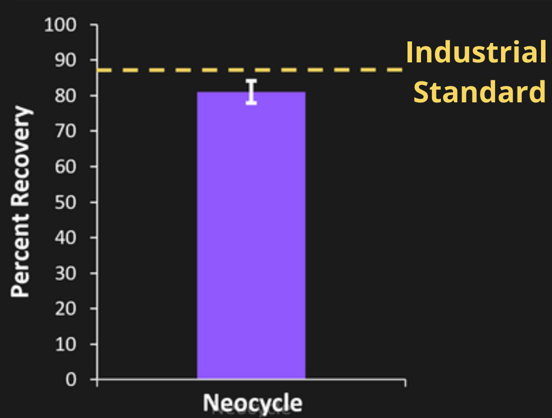
As the demand for rare earths increases exponentially, the race to find new sources of REEs has become a central issue. With new players and technologies fighting for the spotlight, it is time we **secure IP** for our novel REE recovery system to maintain a **competitive edge** once the prototype is finalized.

Through our discussions with local e-waste recyclers, we found that some concerns regarding the implementation of our system include its **profitability** and the **reliability** of our biological approach. To address these concerns, our team places great emphasis on developing a **strong prototype** and producing data to **experimentally validate** the efficacy and reliability of our system.



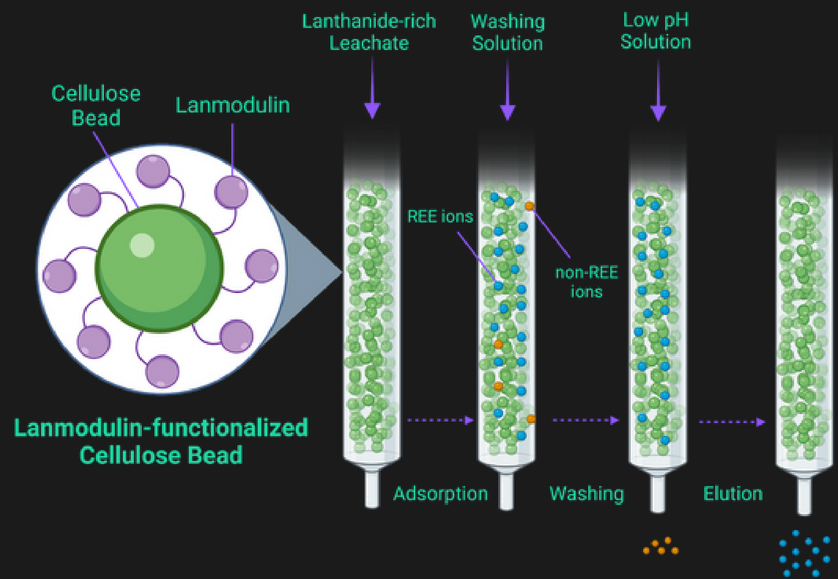
At the heart of our REE recovery system is **Lanmodulin** (LanM), a highly selective REE-binding protein with more than 100-million-fold affinity for REEs over other metals. This allows for the efficient purification of REEs from complex feedstocks, such as e-waste.

By speaking with Dr. Joey Cotruvo, the reseacher who discovered LanM, we learned that besides its great selectivity, LanM can tolerate an extraordinary 50 cycles of metal recovery without degredation. It can also withstand high temperatures and acidic environments, making LanM promising for use in industry, which often necessitates harsh physicochemical conditions. **With impressive selectivity, thermostability, pH stability, and reusability, LanM is a robust protein with the potential to be an effective solution to the REE scarcity problem.**



We have been able to successfully demonstrate a proof of concept (POC) of our process by proving that Neocycle meets industry standards in terms of REE recovery efficiency. LanM's high affinity for REEs allows it to recover REEs with an efficiency of **81%**. This is highly comparable to the industry standard, which has an efficiency of 88%. Current industry standards are energy-expensive, requiring a temperature of up to 1400°C. Our POC operates **at room temperature with minimal energy requirements**. This provides a massive competitive advantage in terms of operating cost and environmental impact.

To bring our solution to industry, we prototyped a design to tangibilize LanM. By incorporating LanM into an affinity column, we can feed solubilized e-waste through and LanM will latch onto all the REEs present while the rest of the metals wash through. According to representatives of local e-waste recycling facilities, existing systems are already in place that will allow the capture and recovery of non-REE metals. Our column is designed so that e-waste can be fed through the column continuously, allowing for a highly efficient REE recovery process.

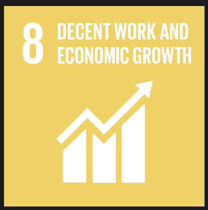


After discussing our scheme with Noah Chemicals, a chemical supplier, we aimed to ensure that the product of our system is in a commercial form. NEOCYCLE is designed to achieve this as the REE metals collected from our system is projected to be purer than the slurry they currently receive from mines. This has the potential to incur less chemical processing on the supplier end being sold to various industries, such as the electronics manufacturing industry.

NEOCYCLE is carefully designed with SDG 12 and SDG 8 in mind.

Neocycle aims to divert REEs from landfills and back into use. Our environmentally sound and socially responsible solution aims to reverse the adverse impacts of rare earth mining and provide a path of reintegration for critical materials. In addition to circulating a supply line for REEs, all major components that go into our recycling units are circular. The four major components of our recycling unit are:

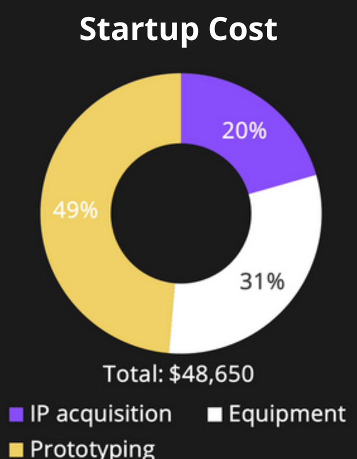
- → **Lanmodulin** protein can be reused over 50 cycles without decreasing binding capacity. It is produced by bacteria using nutrients derived from byproducts of the wine/bread making process. Upon finishing its lifecycle used proteins could be composted and used as organic fertilizer.
- → **Cellulose** is non-reactive, so it can be used repeatedly without the need for replacement. Cellulose would be produced from a bacteria culture using nutrients derived from waste. At the end of its lifecycle, sustainable material applications such as textiles.
- → **Citrate** is derived from agricultural waste fermentation. After use in our system, it can serve as a nutritional supplement for the growth of our bacteria cultures.

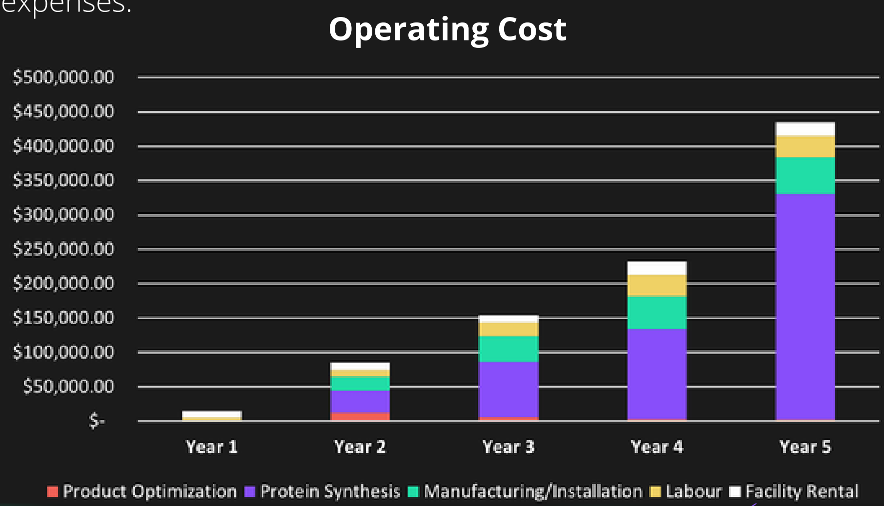


We aim to achieve higher levels of economic productivity by ensuring Neocycle stimulates local economies. Our conversations with the Alberta Recycling Management Authority and local e-waste recycling facilities revealed that one of their main priorities is increasing economic opportunities. Processing e-waste locally allows for less transport costs, which constitutes the second highest line item on one facility we talked to. We strive to expand the workforce through sustainable measures and financially-sound labour environment.

COST ANALYSIS

Over the first 5 years, we will be focusing primarily developing our prototype, ensuring that we have the right equipment, and securing intellectual property. In the years beyond that, our operating costs will be primarily driven by activities aimed at expanding our clientele i.e. synthesizing more protein to meet demand and the associated manufacturing and installation expenses.

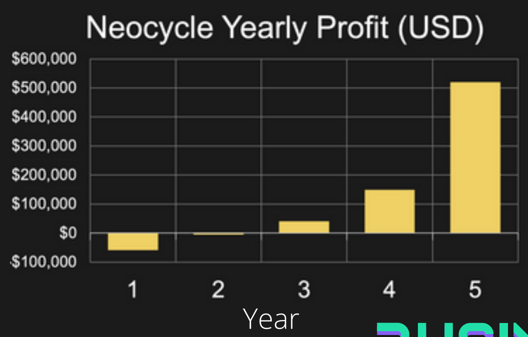




GENERATING REVENUE

Our models estimates a revenue of $80,000 USD/customer. We have established partnerships with 2 recycling facilities already, and plan to launch a pilot program with them in our first year. Upon gaining traction, we will increase our number of yearly customers. With this projection we will break even after 3 years.

Our system is also highly profitable for our customers. Each recycler is estimated to generate an additional $100,000 USD/year of profit by implementing Neocycle.



SWOT

STRENGTHS:

- Partnership with local e-waste recyclers
- Flexible and easily implementable
- Repurpose waste into value-added product
- Successful proof of concept

WEAKNESSES:

- Difficult scale-up path to enter global market
- Low e-waste recycling capacity (only 17% recycled annually in Canada)

OPPORTUNITIES:

- Increasing demand for REEs reveals market gap
- Establish a new and accessible source of REEs
- European Commission promotes e-waste recycling

THREATS:

- Growing demand for REEs might stimulate competition for us
- Recyclers are hesitant to adapt new technologies until efficacy has been proven

BUSINESS CANVAS MODEL

KEY PARTNERS

Short term

- Local (provincial) e-waste recyclers:
  - E-cycle solutions
  - Quantum lifecycle
- Alberta Recycling Management Authority (ARMA)

Long term

- National and international e-waste recyclers
- The European Commision

KEY ACTIVITIES

Short term

- Securing IP rights
- Prototype development
- Local pilot program

Long term

- Scale-up for global market
- Industrial optimization
- Clientele expansion

KEY RESOURCES

- Existing partnership with ARMA
- Extensive academic and industrial network

VALUE PROPOSITION

- A cost-effective and sustainable system for selective REE recovery from e-waste
- A value-added, modular system that easily integrates into existing e-waste recycling processes

CUSTOMER RELATIONSHIPS

- Direct contact with customers to maintain product support & allow for continuous optimization and improvement

CHANNELS

- Direct distribution channel
- Partner channels by seeking opportunities from ARMA

CUSTOMER SEGMENTS

- E-waste recycling companies
- REE refineries and processors
- Electronics manufacturing companies
- E-waste management regulatory bodies

COST STRUCTURE

Fixed-capital costs

- Research and laboratory equipment
- IP acquisition

Operating costs

- Laboratory space rental
- Labour cost for employees
- Product development optimization
- Protein production and distribution

REVENUE STREAMS

One time Fee

- Recycling system installation
- System operation training
- Customer-tailored optimization plan

Recurring Fee

- Recycling unit refills
- System maintenance and repairs

1 CONSUMER ENGAGEMENT

Our system will leverage the formal processing in the existing e-waste management infrastructure. Still, a significant fraction of e-waste does not go through such channels, thus needing an **attitudinal shift** from the general public. We launched a **public survey** to elucidate consumer e-waste handling, and we are working with our **university's sustainability office** to launch targeted campaigns starting with our local university community.

2 SCALE-UP PROTEIN PRODUCTION

Genetically engineered *E. coli*, the **industry standard** as it is a model organism, is used to synthesize a protein that can bind to cellulose on one end and to REEs on the other. While this is feasible on a laboratory scale, doing so on an industrial level requires **process optimization**. Hence, the team is experimenting with different genetic constructs for various protein synthesis pathways that are **scalable, efficient, and cost-effective**.

3 INTELLECTUAL PROPERTY CLAIMS

Although the patent claims on lanmodulin may limit technologies such as ours, the pending status of the application makes this threat uncertain. We consulted **Innovate Calgary**, a transfer and business incubator, and Evan Nuttall and Robert Holthus, patent lawyers from **Smart & Biggar LLP** — a leading firm for intellectual property. They advised us to **finalize a prototype** first before initiating further action. In the future, we will look into **licensing negotiations and reevaluation** after patent finalization.

4 TARGETING RELEVANT MARKETS

E-waste management is a complex issue that lies at the intersection between governmental regulatory bodies and industry. Therefore, it is critical that we determine the **relevant target markets**. We are participating in **Launchpad**, a competitive entrepreneurship program offered by the University of Calgary, and also working with the **Alberta Recycling Management Authority** to identify local avenues for implementation.

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