Providing a secure supply of rare earth and specialty metals for advanced electronics and beyond

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Rare earth elements are critical to modern life. Rare earths have become indispensable and, in many cases, irreplaceable components of materials that are essential in modern life.” - C&E News Washington 2017
SUPPLY BOTTLENECK = PRICE VOLATILITY

U.S. is 100% reliant on foreign critical minerals; Demand grows 5% annually
-U.S. Department of the Interior 2017; C&E News 2017

CNN, Dirty Energy, May 1, 2018
The world’s most valuable companies *rely* on these metals in the products they sell.

- **Apple**: $184B; 1st
- **Google**: $142B; 2nd
- **IBM**: $46.8B; 10th
- **Intel**: $39.5B; 15th
- **Tesla**: $4B; 98th

*Brand Value (USD); Brand Ranking*
Interbrands 2017; Forbes 2017
OUR PREMISE: REUSE THE SECONDARY SUPPLY

EARLY DESIGN CHOICES

1. Design for disassembly
2. Materials for substitution

Short-term market

Manufacturing processes that enable use of recycled materials

Long-term market

Technologies to separate commercially-desirable outputs (i.e. high purity materials)

Manufacturing advances

End-of-life innovations

4. Technology interventions to enable e-waste recovery
5. Methods to separate e-waste components
6. Technologies to digest and recover mixed rare earth and specialty elements

O’Connor et al., ACS Sus Chem Eng 2016

Right images: Apple at work to recover source materials

Turn the device you have into the one you want.
Trade in your eligible device for an Apple Store Gift Card. If it’s not eligible for credit, we’ll recycle it for free. No matter the model or condition, we can turn it into something good for you and good for the planet.

Select your device to get a trade-in estimate.
Copper (Cu) oxide
Europium (Eu) oxide

THE NTH ADVANTAGE: NANO-ENABLED ELECTROCHEMICAL METAL RECOVERY

Mixed Metal Solution (e.g., Cu and Eu)

Voltage 1
Voltage 2

99% Cu recovered
86% Eu recovered
AND YES, WE CAN DO THAT TOO

A route to LiCoNi batteries

89% Cobalt recovered
73+% Nickel recovered

Note: Lithium passes through stack
Investment needs:
- Manpower for pilot scale device design
- Consumables
- Infrastructure for production and early sales

Test CNT membranes for improved chemical stability and decreased cost

Develop and test pilot scale device; economic viability assessment

Customize operating parameters for target manufacturing streams

Start: May 2018
Lab Scale Multi-Stage Device

May 2019
Pilot Scale Device for Commercialization

Start: May 2020
Pilot Scale Device for Commercialization
WE ARE REDEFINING THE METAL SUPPLY CHAIN
WE ARE THE $N^{TH}$ CYCLE TEAM

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**INNOVATION:** Nano-enabled Electrochemical Precipitator for Rare Earth Metal Capture

**IMPACTS:**
- Redefined metal supply chain
- Secure, domestic resources
- Reduced price volatility
- 10-20 fold reduction in greenhouse gas emissions relative to mining primary ores; reduced toxic emissions; less conflict
- *An unparalleled technology to separate rare earth elements without the use of large-volume solvent separations*

**POTENTIAL MARKET:** $6.5 Billion Rare Earth Element Market:
- **INCLUDING:** advanced electronics manufacturers
- **PLUS:** entire LiCoNi battery market