IGEM Grant Report

☐ Progress (due January 1) ☐ Annual (due July 31) X Final (due August 31)

IGEM Grant # IGEM 25-007 Principal Investigator Vivek Utgikar
Name/Full Title of Project Recovery of Critical Materials from E-Waste
Submission Date 08/31/2026 Primary Institution University of Idaho

Section 1: Project and its goals

The overall goal is to develop an efficient and environmentally responsible recycling pathway consisting of oxidation, solid-state chlorination, and electrochemical reduction to recover Nd from spent NdFeB magnets into high-purity neodymium metal. Conceptual schematic of the process is shown below in Figure 1.

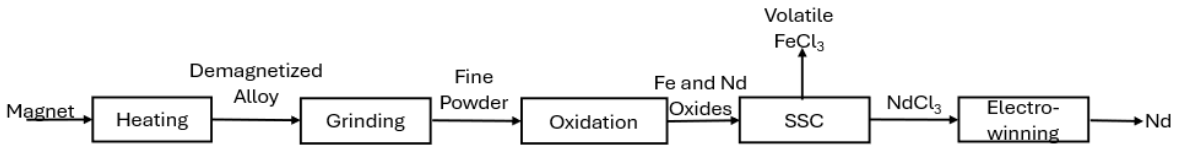

Figure 1. Process schematic for pyrometallurgical recovery of Nd

Section 2: Summary of accomplishments and future plans

Accomplishments:

1. Successful demagnetization and size reduction of magnets
2. Optimized conditions (550°C, 4 hours) for complete oxidation of metals while avoiding $NdFeO_3$ formation
3. Optimized conditions for NH_4Cl-mediated solid-state chlorination (320°C, 1 hour, 6x excess chloride, Ar sweep) resulting in >98% Nd retention in the solid residue alongside >99% selective $FeCl_3$ volatilization accomplishing effective separation between Fe and Nd
4. Molten chloride and fluoride electrolyte systems examined (operating temperatures 350°C - 450°C) using Cyclic voltammetry (CV) and chronoamperometry were conducted across varying $NdCl_3$ concentrations to determine the reduction kinetics and electrodeposition behavior of neodymium.

Future Plans (Past Project Completion): 1. **Electrolyte Optimization:** Select the optimum molten salt composition based on current efficiency and deposition purity across the 350–450°C range. 2. **Deposit Characterization:** Analyze deposited Nd using SEM-EDS and XRD to evaluate morphology, phase purity, and residual iron contamination. 3. **Mass Balance & Flowsheet Integration:** Establish a comprehensive mass balance for the integrated oxidation–chlorination–electrowinning flowsheet to determine overall recovery yields and reagent recycling feasibility.

Section 3: Summary of budget expenditures

The total budget for the project was $140,000 consisting of personnel costs (salary and fringe) - 62.7%, operating expenses – 19.2% and student tuition/insurance – 18.1%. The

overall expenditure was $132,676 (94.8%) as detailed in the expenditure report attachment (Section 7).

Section 4: Economic development/impact

List of Publications and Manuscripts:

1. Valappil, D. A., Raja, K. S., & Utgikar, V. (2026). Review on Oxidation of Nd–Fe–B Magnets: Mechanisms, Kinetics, and Implications for Neodymium Recovery. *High Temperature Corrosion of Materials*, *103*, Article 88, pp. 1–56. DOI: 10.1007/s11085-026-10446-7.
2. Valappil, D. A., Raja, K. S.,Utgikar, V.& Diba Z. Kinetic Analysis and Phase Transformation During Oxidation of Nd–Fe–B Magnet Powder. *(In preparation)*.
3. Valappil, D. A., Raja, K. S., & Utgikar, V. Selective Separation of Iron from NdFeB Scrap Through Oxidative Roasting Followed by Low-Temperature Chlorination and Volatilization. *(In preparation)*.
4. Valappil, D. A., Raja, K. S., & Utgikar, V. Electrodeposition Behavior and Reduction Kinetics of Neodymium in Molten Chloride and Fluoride Electrolytes. *(In preparation)*.

Collaborations and planned activities are described in section 6.

Section 5: Participants

Vivek Utgikar, PI, faculty: Project management and supervision of research effort; Approval of experimental design, and guidance on data interpretation and analysis; Budget and expenditure management.

Krishnan Raja, co-PI, faculty: Supervision of research effort; Assisting PI in directing experimental effort and data interpretation/analysis.

Dijina Asarinte Valappil, graduate student: Execution of project tasks including experimentation, theoretical modeling, sample analysis and data interpretation.

Diba Zadehgol, Mahir Adib, and Zach Greene, undergraduate students: Assisting graduate student in conducting experiments and laboratory tasks.

Section 6: Long-term sustainability plan

Collaborations:

Proposals: 1. GenNext Materials and Technologies, LLC, Reno, NV, DOE-STTR. 2. United States–India Science and Technology Endowment Fund (USISTEF).

Industry Outreach: 1. Sunshine Silver Mining, Idaho. 2. Idaho Strategic Resources, Inc., Idaho. 3. Tronox

Idaho National Laboratory outreach: Discussions with Critical Materials Research group (Robert Fox and Caleb Hill). Identified various opportunities (ARPA-E, DoE, DoW, INL LDRD, etc.). NDA in progress.

Section 7: Expenditure Report

Attachment “IGEM 25-007 August 2026 Final Report Expenditure Attachment.docx”.

Section 7: Expenditure Report

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Recovery of Critical Materials from E-Waste

Expenditures

Category	Budgeted	Spent	Balance
Personnel (Salary + Fringe) PI, co-PI, Students	87,752	88,989	(1,237)
Operating Expenses (Materials/Supplies, Publication)	26,832	20,158	6,674
Graduate Tuition and Health Insurance	25,416	23,529	1,887
Total	140,000	132,676	7,324