

RECOVER Project Descriptions

Realize Energy-rich Compound Opportunities Valorizing Extraction from Refuse waters

Northwestern University – Chicago, IL

Nitrogen and Phosphorus Recovery via Intensified Microbial Extraction (N-PRIME): A Biotechnological Approach for Valorization of Municipal Wastewater - \$2,718,183

Northwestern University will use microbes to selectively concentrate nitrogen and phosphorus in wastewater by three orders of magnitude and enable them to be captured as market-valuable products. This technology, called N-PRIME, utilizes self-replicating, self-assembling, and self-repairing bacteria to enable continuous recovery of high value amino acids and market-valuable fertilizer at greater productivity and lower cost than state of the art methods. The technology would be used to decrease energy-related imports of phosphate and ammonia as well as improve resilience, reliability, and security of the supply chain by onshoring production via a scalable approach directly adaptable to existing wastewater treatment infrastructure.

University of Texas at Austin – Austin, TX

Biomimetic Membranes for Electrochemical Nutrient and Mineral Recovery from Wastewaters - \$2,000,000

The University of Texas at Austin will integrate lab-scale innovations with industrial materials and process scale-up to develop scalable, membrane-based electrochemical nutrient and critical metal recovery systems. The intended product is a novel scalable bioinspired membrane materials platform that selectively targets lithium, ammonium, and other metal ions from oil and gas produced water as well as phosphate and ammonium ions from municipal wastewater. Success would enhance U.S. competitiveness in energy industries by creating a local resource-based stream of critical materials.

Johns Hopkins University – Baltimore, MD

Bioacid-Mediated Electrowinning for Cobalt and Nickel Recovery from Wastewater - \$2,400,000

The Johns Hopkins University team will develop and demonstrate a modular and scalable process to extract cobalt and nickel from aqueous waste streams. Their technology features a multistage evaporative crystallizer that enables front-end concentration, followed by downstream electrochemical reactors that sequentially recover metallic cobalt and nickel. To address the longstanding challenge of cobalt–nickel selectivity, the solvation environment of metal ions will be precisely tuned using bioacid ligands. The system will be compatible with existing infrastructures and enable the recovery of critical minerals from waste streams and byproducts of U.S. industrial operations such as electronic waste recycling, lithium-ion battery manufacturing, produced water, and mining discharge.

University of Connecticut – Storrs, CT

Ammonia and Phosphorus Fractionation from Anaerobic Digesters with Ceramic Membrane Distillation - \$3,000,000

The University of Connecticut team will demonstrate a hybrid system capable of recovering greater than 90% of phosphorus and ammonia from wastewater as high-value liquid products. The integrated process will combine ceramic vacuum membrane distillation to extract ammonia and bipolar membrane electrodialysis to capture phosphorus as phosphoric acid. The team will use this Intensified Anaerobic Digestion with Resource Recovery (IADRR) process to derisk the individual unit operations and then conduct a field demonstration at a wastewater utility in Massachusetts. The project will deliver a validated, scalable pathway for nutrient and

critical material recovery that strengthens U.S. wastewater infrastructure, improves water quality, saves electricity, and creates new revenue streams for utilities.

Columbia University – New York, NY

PURE HARVES2T: Produced water Utilization for Recovery of Energy materials—High-value Advanced Resource Valorization using Emerging Switchable Solvent Technologies - \$1,655,334

Columbia University will evaluate two solvent-based processes for the recovery of critical energy materials lithium and magnesium from wastewater. First, temperature swing solvent extraction (TSSE) will employ a thermally responsive solvent to concentrate lithium in wastewater to the threshold of 6,000 mg/L for lithium recovery. Second, thermomorphic hydrophilicity base-induced precipitation (THBIP) using a recyclable amine base will be used to selectively extract and recover magnesium. The integrated THBIP-TSSE process unlocks cost-competitive lithium and magnesium recovery and simultaneously desalinates produced water, reducing waste stream volumes by >99% and providing reusable water streams.

University of Missouri – Columbia, MO

Development and Demonstration of a Highly Selective Rare Earth Elements Recovery System Using Novel Ion Imprinted Media - \$2,800,000

The University of Missouri aims to recover valuable rare earth elements like neodymium, praseodymium, and terbium from mining waste using a special technology called ion-imprinted polymers (IIPs). These IIPs are designed with custom "cavities" that specifically bind to these rare earth elements. The team will use artificial intelligence tools to systematically evaluate materials to reduce costs and enhance the IIP's performance. The intent is to develop a scalable process for extracting high-value and strategically important rare earth elements from domestic mining waste streams, such as natural acid rock drainage and acid mine drainage.

Stanford University – Stanford, CA

Electrochemically Driven Wastewater Refining for Ammonia, Phosphate, and Magnesium Recovery from Anaerobic Digestate - \$3,000,000

Stanford University will develop a novel Electrochemical Stripping, Adsorption, and Precipitation (ESAP) process to enable recovery of commercial-grade ammonia, phosphorus, and magnesium products from waste streams at water resource recovery facilities. They will investigate and derisk the ESAP process to convert crude wastewater into multiple element-specific market-valuable products to meet regional demands. The team will prototype their process, integrate modified membranes and antifouling improvements, investigate opportunities for market entrance, and advance toward commercialization.

University of California, Davis – Davis, CA

Innovative Biocatalysts through Protein Engineering and Synthetic Biology for Efficient, Highly Selective, and Scalable Recovery of Rare Earth Elements - \$3,000,000

The University of California, Davis is engineering a bacterium to produce a metal-binding protein to selectively extract the rare earth elements (REE) from acidic mine-influenced waters. Their technical approach applies artificial intelligence to protein design, measurement, and acid-compatible process development in an iterative, closed loop process. The technology enables selective, low-pH recovery and concentration of the REE at the source. This could help tap into large domestic REE inventories trapped in refuse waters such as acid mine drainage, tailings liquor, and industrial leachates.

Carollo Engineers, Inc. – Costa Mesa, CA

Selective Recovery of Critical Metals from Produced Water Using Engineered Ferritin Protein Nanocages - \$2,423,292

Carollo Engineers is developing a biotechnology-driven platform using engineered ferritin protein nanocages (PNC) to enable selective and sustainable recovery of critical metals including lithium, cobalt, nickel, dysprosium, and neodymium. Ferritin is a naturally occurring protein that self-assembles into highly organized nanocages with negatively charged internal cavities capable of adsorbing and sequestering metal cations. The team will conduct machine learning-guided protein design to develop ferritin variants with enhanced selectivity and affinity for specific critical metals. The ferritin PNCs operate under mild environmental conditions, require minimal chemical and energy inputs, and can be regenerated repeatedly through controlled assembly and disassembly in a reconfigurable resource recovery process. The domestic critical metals supply streams created will help to eliminate American dependence on imported supplies.

Phoenix Tailings, Inc. – Woburn, MA

SELECT: Selective Extraction via Ligand-Enhanced Complexation and Thermal separation - \$1,600,000

Phoenix Tailings intends to use tailored ligands to form rare earth elements (REE) and critical mineral (CM) complexes to promote extraction of pure, usable salts from aqueous waste streams. The team will study various molecules to create selective, temperature stable and volatile REE and CM complexes reproducibly at a lab scale. Once the most successful complexes have been identified, the team will determine optimal conditions for selective extraction from both produced and real-world wastewater using fractional distillation. Their approach will result in a greater ability to selectively recover REE and CM from feedstocks with less than 1,000 parts per million brine/metal solution. This would help reduce U.S. dependence on foreign resources of REE and CM, bolstering domestic national security and energy security.