Precious Metal Recovery and Recycling for Fuel Cells and Electrolyzers at End-of-Life

DOE Hydrogen Program
2024 Annual Merit Review and Peer Evaluation Meeting

TOPIC C56-11: JOINT AMMTO/HFTO/IEDO TOPIC: FUEL CELL AND ELECTROLYZER RECYCLING

SUB-TOPIC B: Reducing Hazardous Substances in Fuel Cells and Electrolyzer Recycling

Status: Active - In Progress
AMR Project ID# MNF-BIL007
Award: DE-SC0023812

PI: Philip A. Stuckey, PhD
Founder & CEO
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This presentation does not contain any proprietary, confidential, or otherwise restricted information

Project Goal

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Project Topic: Reducing Hazardous Substances in Fuel Cells and Electrolyzer Recycling

Pyrometallurgical procedures for PGM recycling, which apply direct thermal energy to the fuel cell in order to concentrate PGMs, release toxic hydrogen fluoride gas in the process. Our process, performed at room temperature, uses environmentally friendly solvents, reduces the production of hazardous by-products, and manages hazardous by-products in the recycling of fuel cells and electrolyzers

- **80% Reduction in Hazardous Substances**
- **90% recovery of Precious Group Metals (PGMs)**

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Overview

Timeline and Budget

- Project Start Date: 07/10/2023
- Project End Date: 07/09/2024
- Project Budget: $200,000
  - Total DOE Share: $200,000
  - Total Cost Share: $0
  - Total DOE Funds Spent: $144,072
    *As of 03/01/2024

Barriers

- Test MEAs are of laboratory nature and have not been used in real-world environments
- Stability of aging test station caused data processing issues and modification of procedures

Partners

- PI: Thomas Zawodzinski, PhD
- University of Tennessee
  - Subcontract Ratio: 30%
  - Subcontract Amount: $60,000

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Potential Impact

This project will:

- Significantly reduce the waste and toxicity from current state-of-the-art recycling processes
- Recover precious metals for reuse and resell
- Support national security goals through developing robust access to precious metals in country

The project directly relates to the DOE H2 Program by:

- Lowering Greenhouse gas emissions and criteria pollutants,
- Creating skilled and unskilled/high pay jobs in the US,
- Advance clean energy infrastructure,
- Strengthen US manufacturing.

Technology	PMT	HMT	FCR
Investment cost	-	+	++
Operating cost	-	+	++
Recovery efficiency	+	-	+
Energy requirements	-	++	++
Hazard/toxicity	-	-	++

Key:
++ very favorable performance
+ favorable performance
0 regular performance
- unfavorable performance
-- very unfavorable performance

Adapted from Source: Valente Antonio, Diego Iribarren, Javier Dufour. "End of life of fuel cells and hydrogen products: From technologies to strategies." *International Journal of Hydrogen Energy*, Volume 44, Issue 38 (2019): 20965-20977.

Approach

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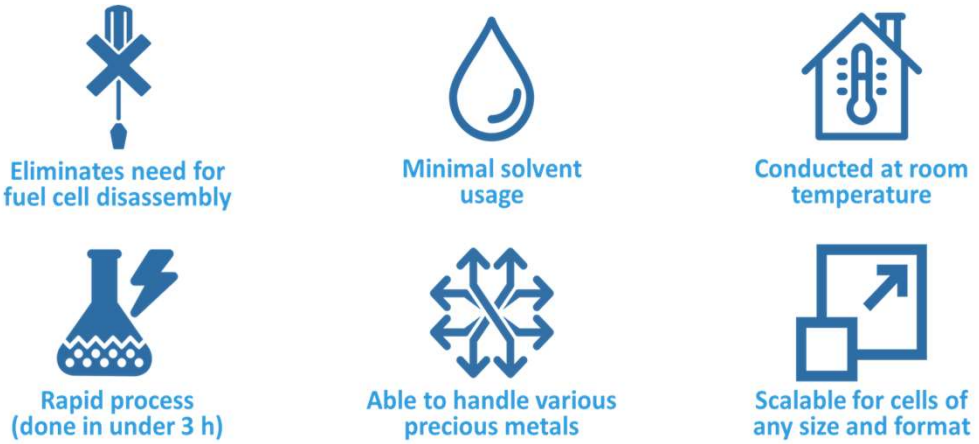
We are a deep tech development company enabling the hydrogen transition

Our goal is to commercialize our non-pyrolytic methodology for platinum recovery from fuel cell electrodes and iridium and platinum recovery from electrolyzer electrodes

Our project outcome will result in cleaner and more efficient recycling processes for fuel cells and electrolyzers delivering an environmental impact while promoting critical materials goals for precious metals compared to pyrometallurgic methods.



Approach: Safety Planning and Culture

RESEARCH PARK AT CHEROKEE FARM

FC Renew priorities a safe work environment

- **Users Understand Risks**
- **Required use of PPE and safety glasses**
- **Attend Safety Trainings and Meetings**
- **Work with University and National Laboratory on best practices**
- **Comply with University of Tennessee Waste Disposal Management Systems**

FC Renew's Laboratory in the Spark Incubator at the University of Tennessee Knoxville

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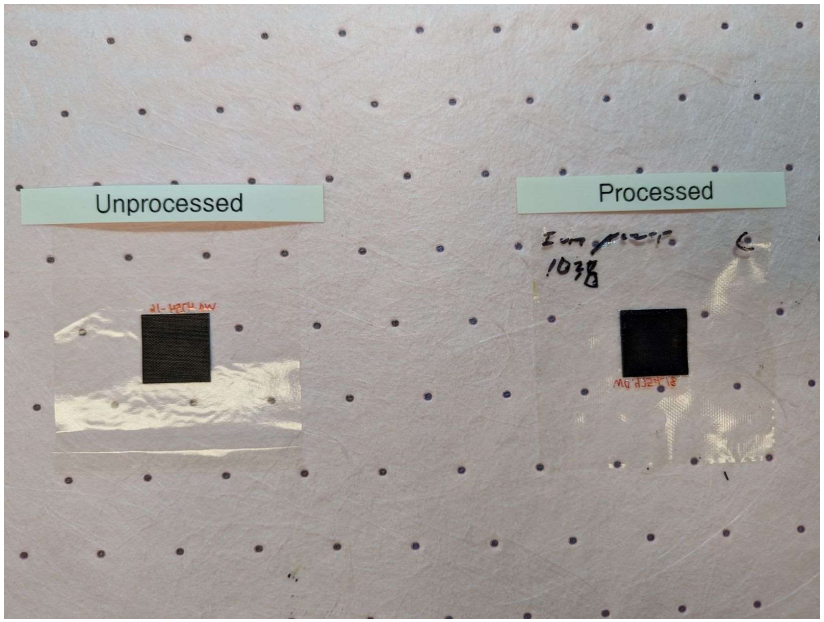
Accomplishments and Progress

Requirements	DOE Targets	FC Renew's Status
Reduction of Hazardous Substances	80%	

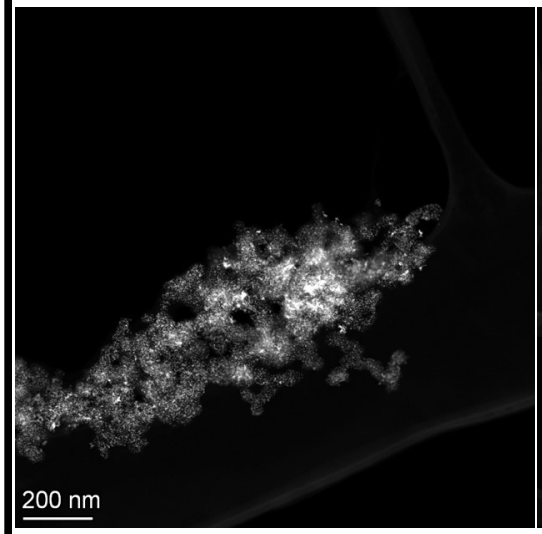
Requirements	DOE Targets	FC Renew's Status
PGM Recovery	90%	14-56%

Minimal Membrane Degradation Effects

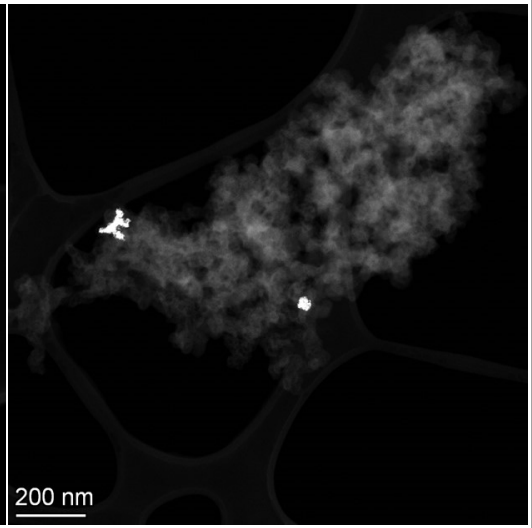


Selective Pt Removal from Carbon Support

Unprocessed



Processed



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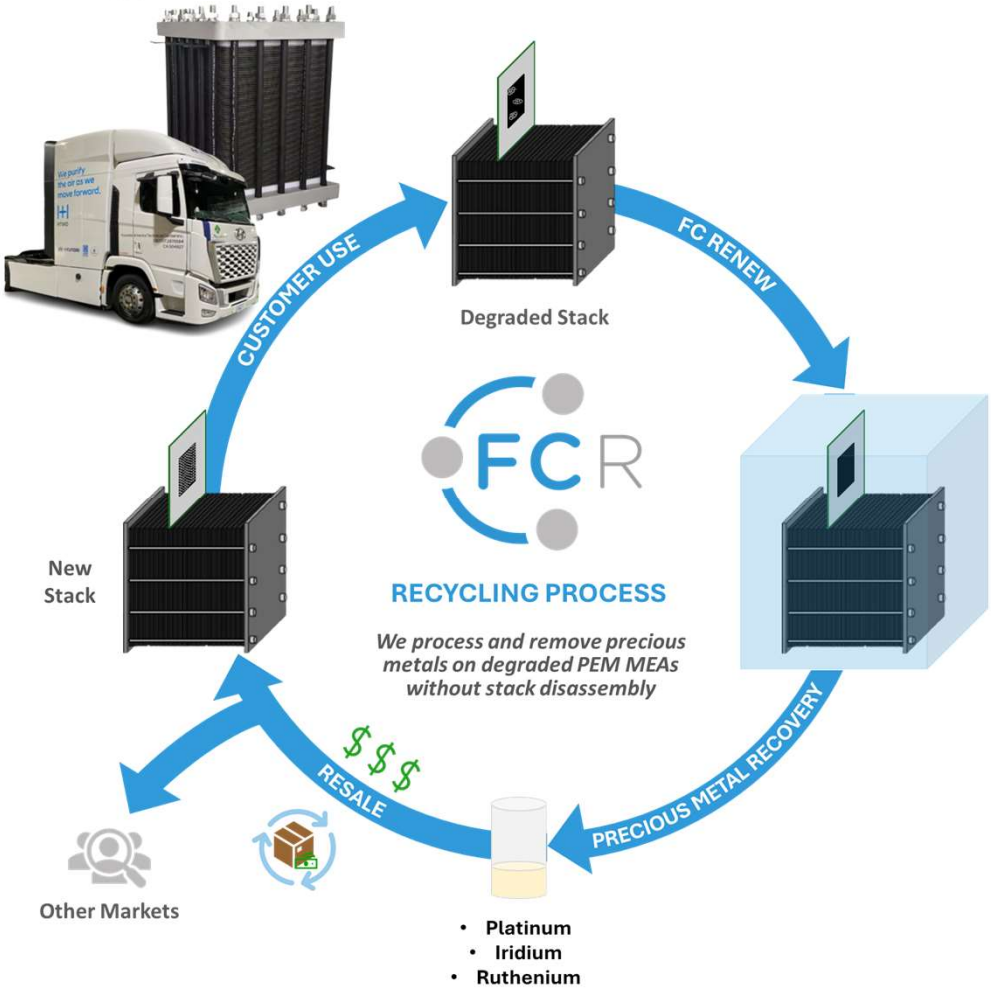
Collaboration and Coordination



Benefits

- ✓ Non-pyrolytic
- ✓ No stack disassembly required

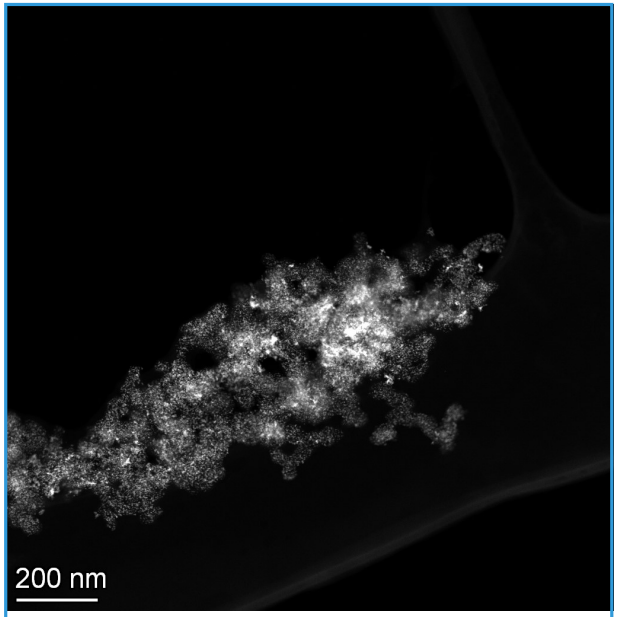
Impact

- ✓ Critical precious metals within our borders promote national security and compliance with executive orders

Impact

- ✓ Prevention of environmental release of toxic HF gas
- ✓ Compliance with future PFAS bans in EU and US markets

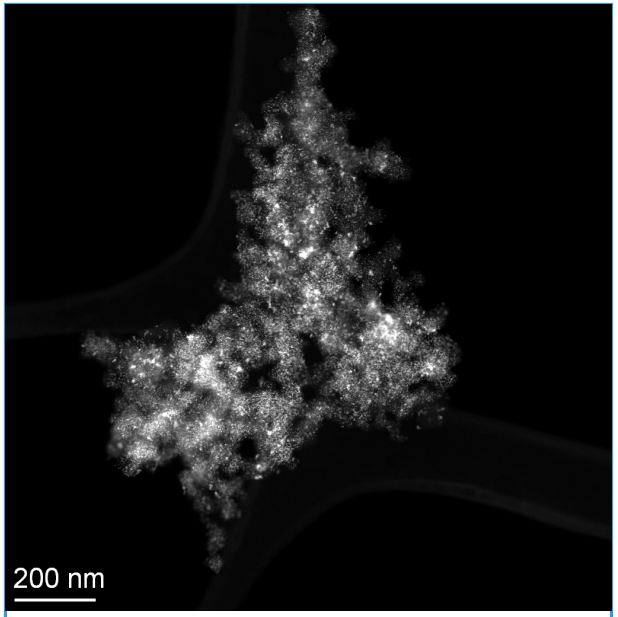
Remaining Challenges and Barriers
Improve Recovery Yield (Interim Results)



New MEA sample

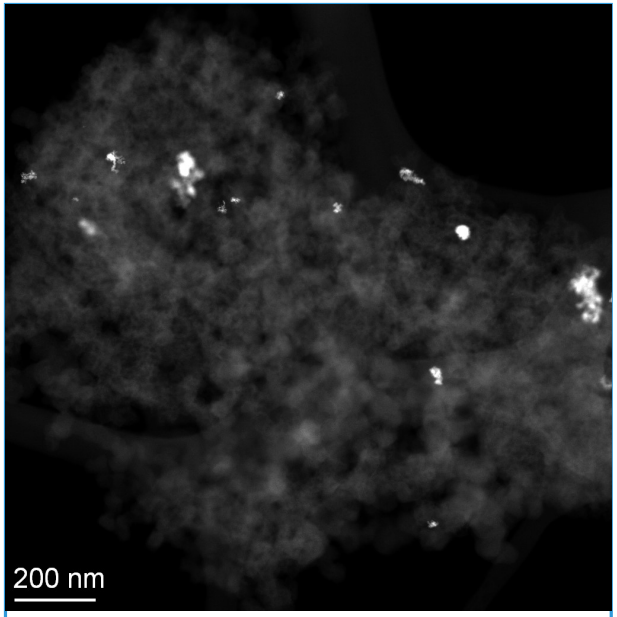
Small and Large Pt

Note: Large Pt >50 nm present in new samples (not commercially optimized particle size distribution)



Early work on single cell PEMFC
-low Pt extraction-

Early Work



Interim Progress on single cell PEMFC
-increased Pt extraction-

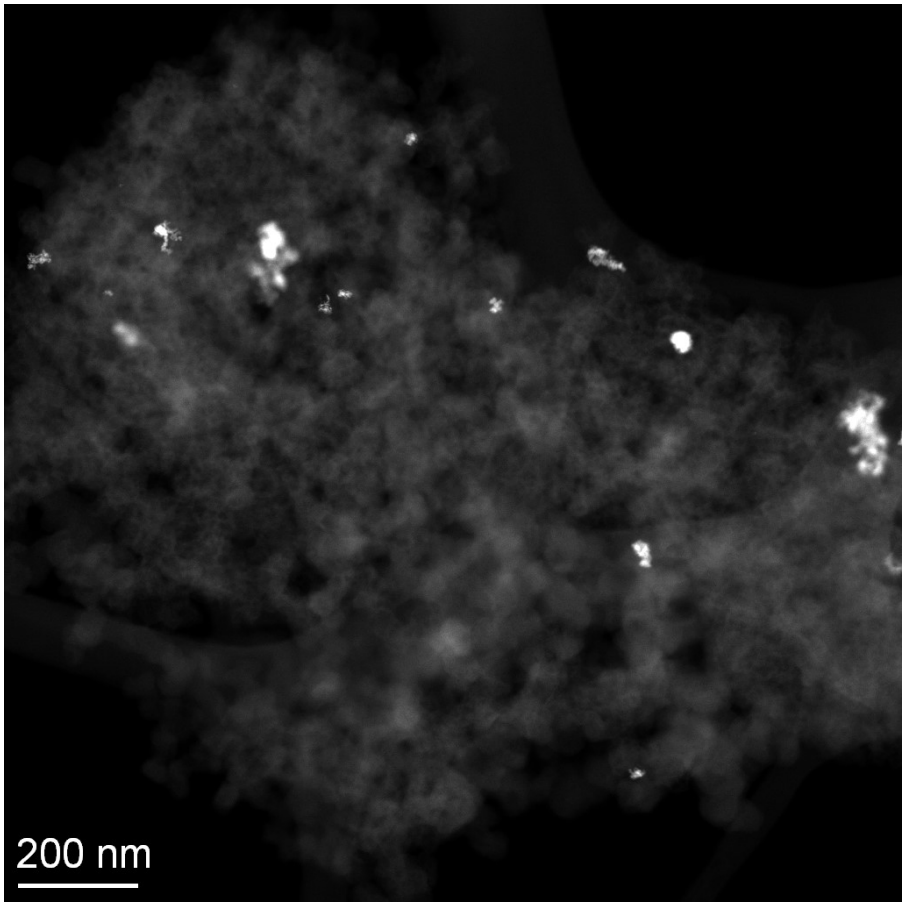
Small Pt Removed
Large Pt Remains

Proposed Future Work

- Pt recovered from 5 cm^2 membrane electrode assembly housed in 5 cm^2 hardware with graphite separators
- Almost complete removal of <20 nm Pt as shown in the STEM micrograph
- Larger Pt particles remain
  - Future work to completely remove Pt
- Larger particles >50 nm are unlikely to present a challenge with extended processing
  - Note: The initial particle size distribution of our test catalyst is poor. Expected particle size distribution at end-of-life[1] is less than the particle size distribution we tested in our experimental procedure.

[1] *H. Yu, M. Zachman, C. Li, L. Hu, N. Kariuki, R. Mukundan, J. Xie, K.C. Neyerlin, D. Myers, D. Cullen, Recreating Fuel Cell Catalyst Degradation in Aqueous Environments for Identical-Location Scanning Transmission Electron Microscopy Studies. ACS Applied Materials & Interfaces 2022 14 (18), 20418-20429*

- **Pt at typical end of life distributions of 5-15 nm <u>can be fully recovered and recycled</u> based on current results**



DEIA/Community Benefits Plans and Activities

FC Renew remains committed to advancing DEIA and participating in Community Activities

Community Outreach

Strong Hiring and Recruitment Practices

Transparent Promotions and Evaluation

Clear Diversity, Equity, and Inclusion Strategies in the Research Environment

Sponsored Senior Design Team at the University of Tennessee

Special Recognition and Awards

EnergyWerx Voucher Recipient Sponsored by U.S. Department of Energy

U.S. Department of Energy site visit at FC Renew's Laboratory on January 22, 2024 for EnergyWerx Voucher Recipients Announcement

SUPPORTED BY

energywerx

STRATEGIC ANALYSIS

Voucher Opportunity 4 – Commercialization Support (EERE)
Provider: Strategic Analysis, Inc.

Technology Transfer Activity

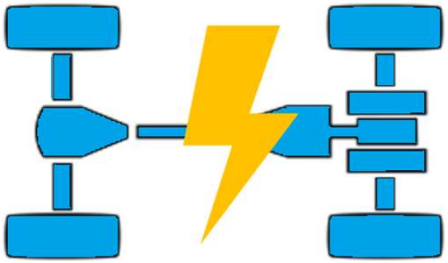
FC Renew filed a Provisional Patent Application 63/640,321, Title: “Fuel Cell and Electrolyzer”

PI, Philip Stuckey, Patent Agent Registration #80,267

Summary

We are a deep tech development company enabling the hydrogen transition

WHY PARTNER WITH US FOR PLATINUM RECYLCING?



End-Of-Life (EOL) stacks need attention, skill, labor, and proper disposal

- **PGMs – Platinum remains in stack at EOL**
  - **Pyrolytic recyclers do not accept assembled stacks**
- **FC Renew processes stacks both owned by individual customers or OEMs at End-of-Life**

FC Renew offers, EOL disposal, platinum recycling, and PGM cost recovery

- **PFAS disposal/upcycling**
- **We accept one or thousands of spent stacks**
- **Optional transfer platinum to preferred vendor**
  - **Provides vertical supply chain security**
- **Environmental Policy Compliance – PFAS release**