



Seminar Series

July 19, 2023

LA-UR-23-28345

I-WEST is a collaborative initiative with partners across the Intermountain West

Co-led by Los Alamos National Laboratory and the University of Wyoming School of Energy Resources

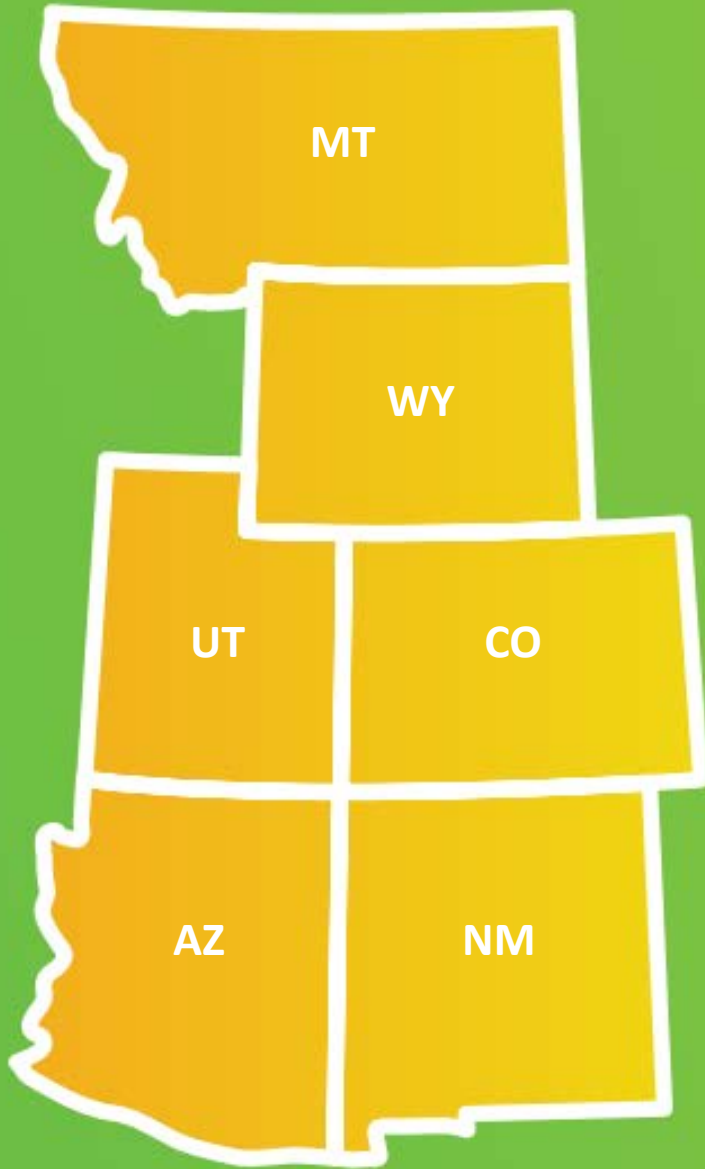


Jolante Van Wijk
Los Alamos National Laboratory



Scott Quillinan
University of Wyoming





I-WEST provides Intermountain West states with data, tools, and information for energy transition planning

- Place-based approaches focus on the unique geographical, environmental, and demographic attributes of the region
- Technology-neutral approach leverages opportunities across numerous symbiotic energy economies
- Integrated approaches to assessing technology readiness in tandem with societal readiness for a just and equitable energy transition
- Community engaged research and coalition building to encourage regional partnerships

Fascinating Fuel Cells



Dr. Daniel Leonard

Los Alamos National Laboratory

- Staff scientist in the Los Alamos Fuel Cell Program
- Works on developing fuel cell and electrolyzer technologies
- Ph.D in chemistry from Oregon State University, M.S. in chemistry from New Mexico Tech, and B.S. in viticulture and enology from the University of California

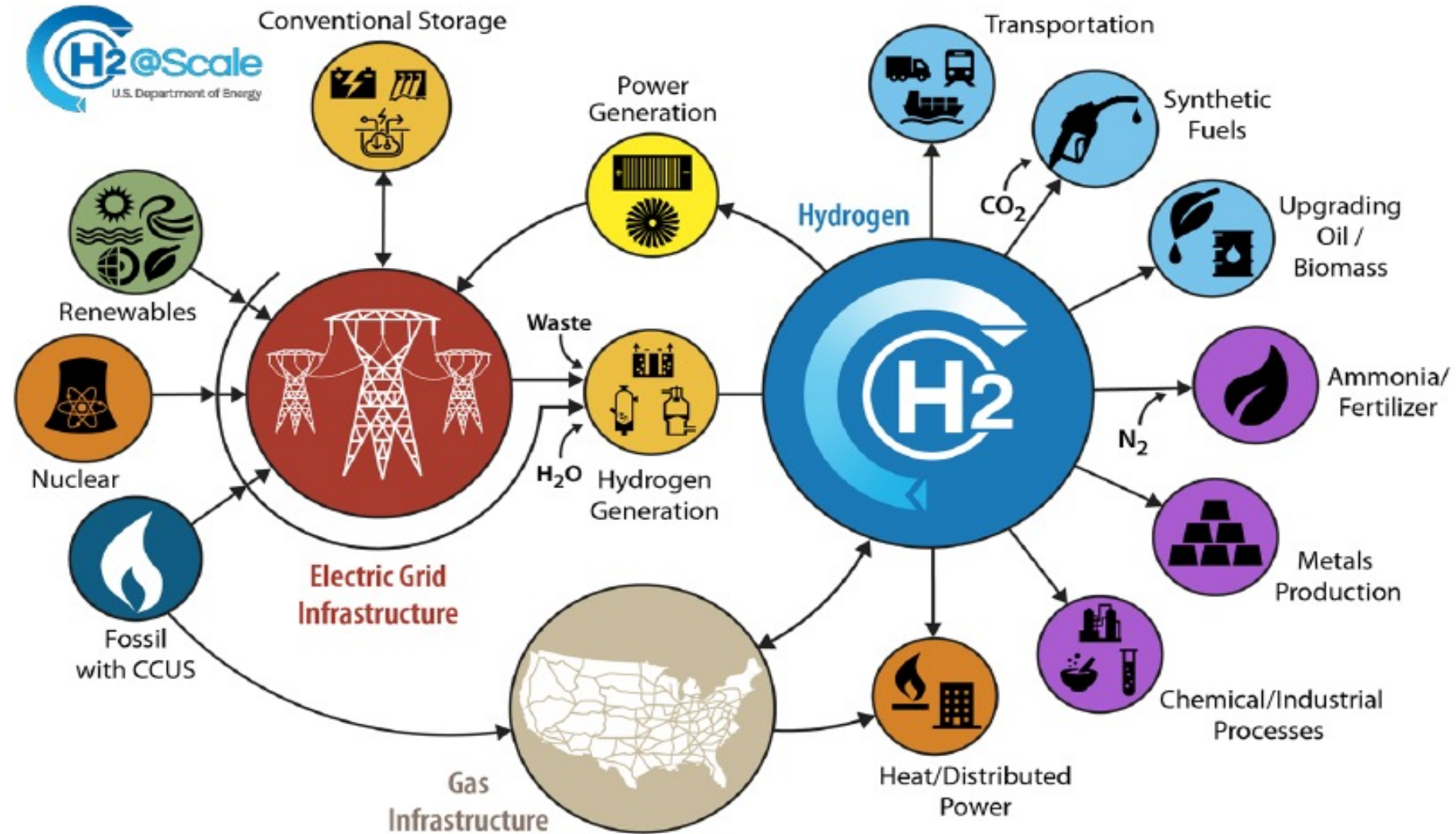
Fascinating Fuel Cells at LANL

July 19, 2023

Dr. Daniel Leonard
MPA-11

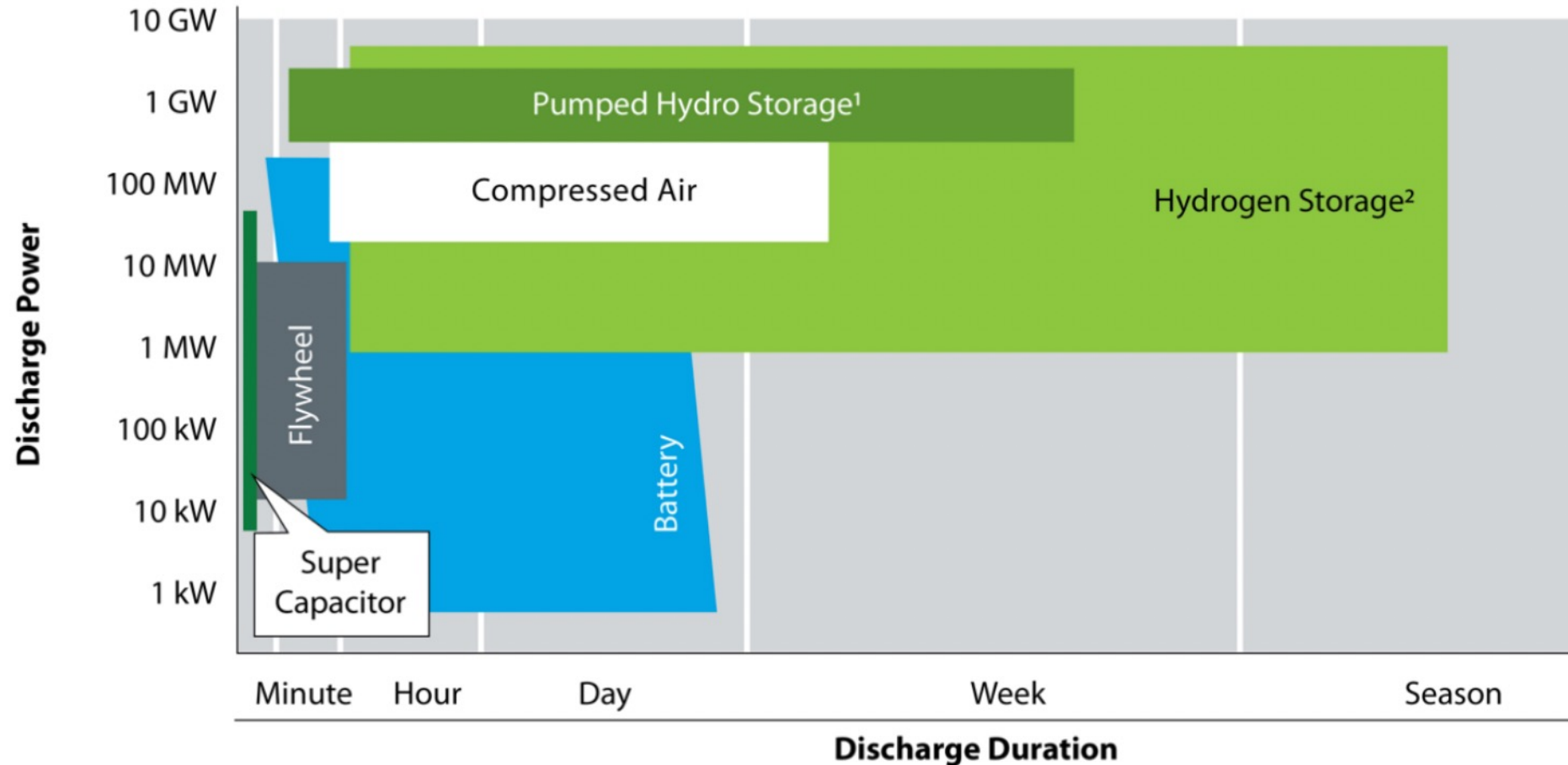
Conceptual H₂ at Scale Energy System*

Decarbonize the Three Energy Sectors Simultaneously



*Illustrative example, not comprehensive

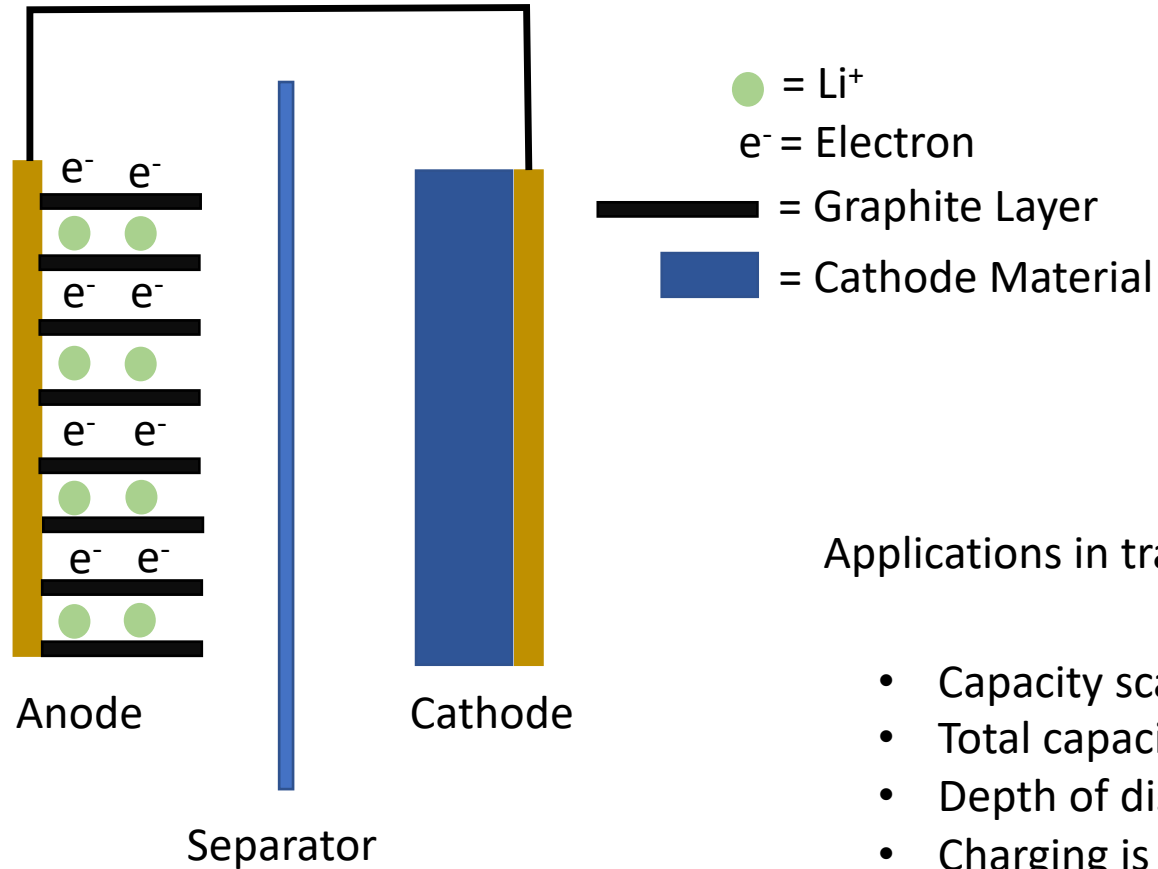
Hydrogen Potential Grid-scale Storage



¹ Pumped hydro capacity is limited due to geographic constraints. Estimated maximum potential is <1% of U.S. electrical energy demand

² As hydrogen, ammonia, or synthetic natural gas

Lithium-ion Batteries



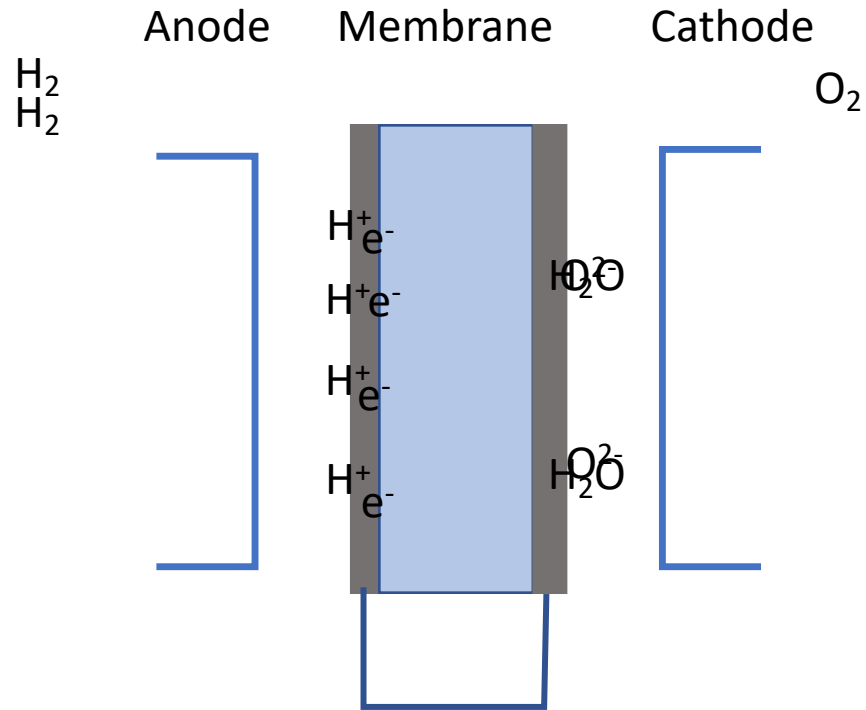
Specific Power Output
0.25-0.35 kW/kg

Efficiency
80-90%

Applications in transport and short-duration energy storage (hours)

- Capacity scales linearly with battery size
- Total capacity is reduced with every cycle
- Depth of discharge is limited to prevent damage
- Charging is slow compared to other vehicles (even with rapid charge)

Hydrogen Fuel Cells



Applications in heavy-duty transport, aviation, shipping



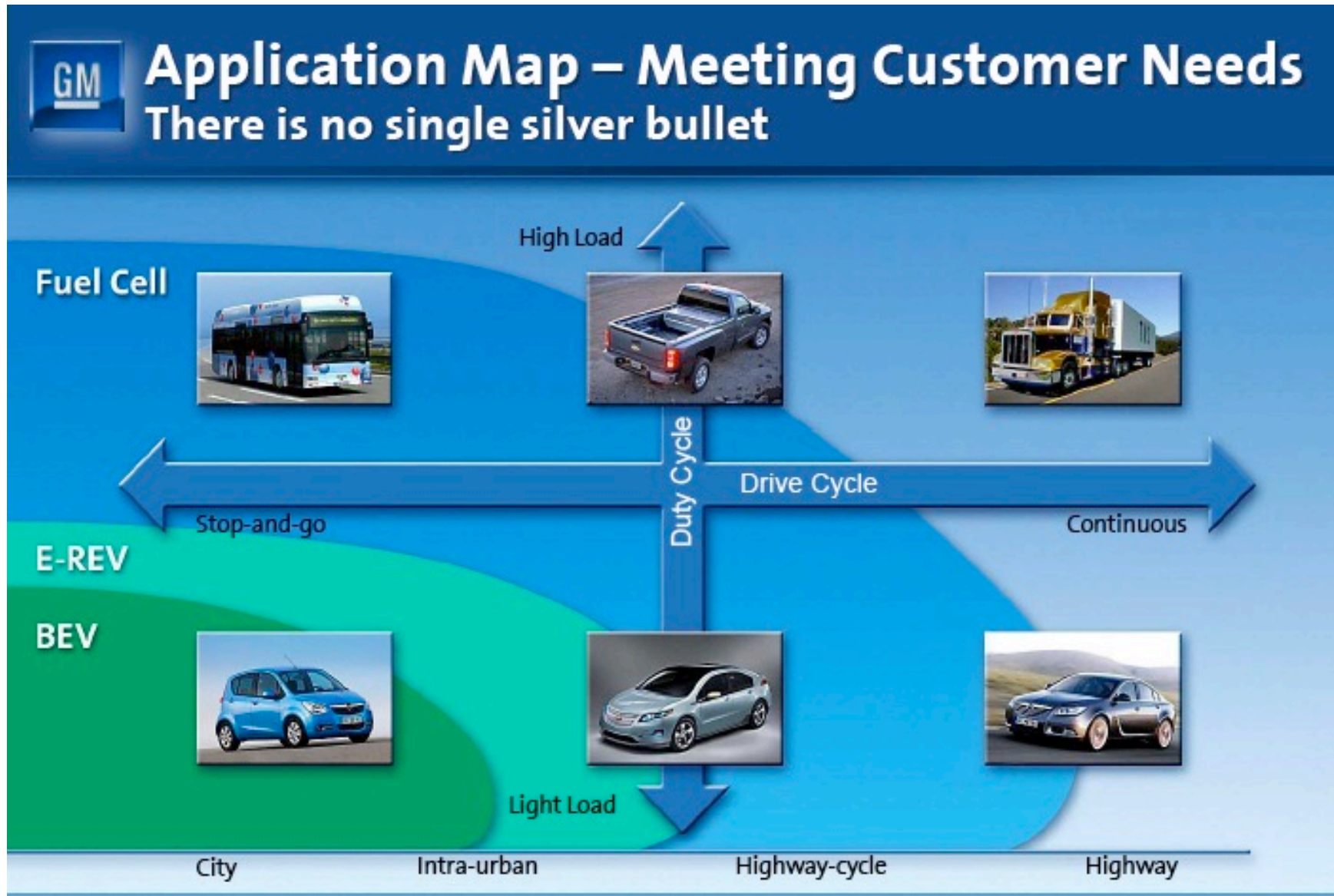
Specific Power Output
5.4 kW/kg



Efficiency
60-70%



Major Auto OEMs Developing PEM Fuel Cells



Daimler, Nissan, Toyota have shown similar strategies
~ All major auto companies have fuel cell vehicle programs including above, plus BMW, Volkswagen, Ford, Honda, Hyundai,



Payload Impact

Payload and Energy Density

One Day of Regional Haul = 350 miles on 2 Shifts

Diesel
Fuel Amount: 70 gallons
Fuel Weight: 500 lbs
Tank Weight: 150 lbs
Total Weight: 650 lbs



Compressed Hydrogen
Fuel Amount: 55 kgs
Fuel Weight: 120 lbs
Tank Weight: 4,200 lbs
Total Weight: 4,320 lbs

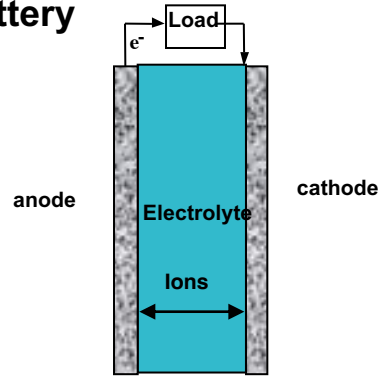


Battery
Energy Amount: 900 kW-hrs
Fuel Weight: 0
Battery Weight: 16,800 lbs
Total Weight: 16,800 lbs

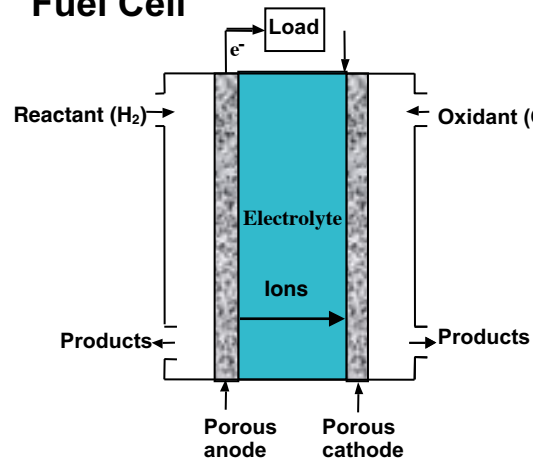


Fuel Cells and Batteries: Range and Refueling

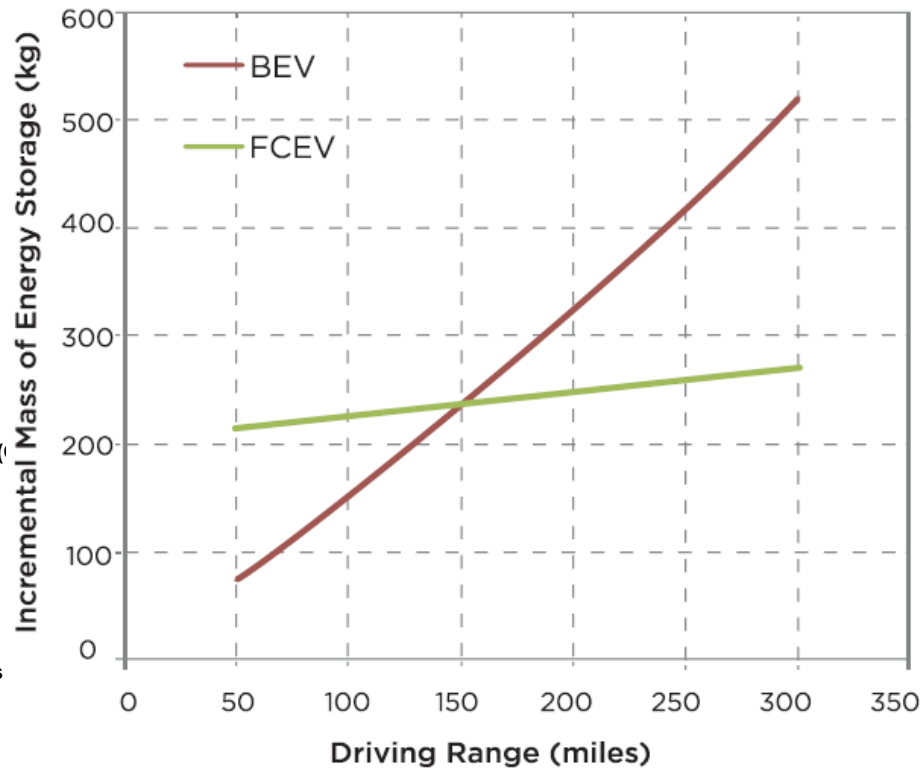
Battery



Fuel Cell



Electric Power System Mass vs. Vehicle Range



Why does it take so long to charge batteries?

Fueling Time Analogy

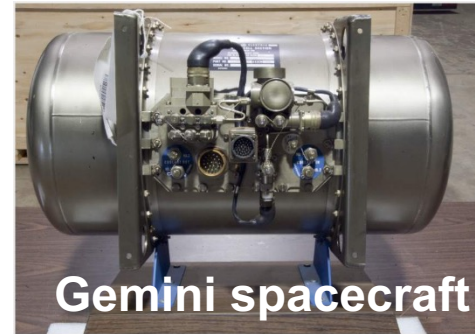
- Pumping 14 gallons of gasoline in 3 minutes is equivalent to **10 Megawatts** of power
- The average hydrogen power flow in 27,000 hydrogen FCEV fueling events monitored by NREL was **1.82 MW**
- A home 120V/20A circuit has a maximum power rating of 1.9 kW, which is 5,300 times slower than pumping gasoline and 950 times slower than pumping hydrogen
- A Type-2 240V 40A circuit has 7.7 kW power, or 1,300 times slower than gasoline and 240 times slower than hydrogen.

Advantages: energy density (up to >6000 Whr/kg based on fuel, batteries up to 150 Whr/kg), refuel versus recharge

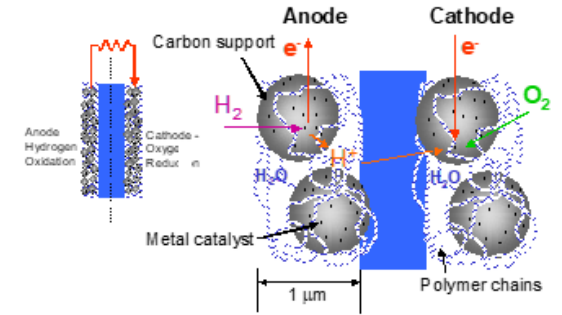


Fuel Cell R&D at Los Alamos

- One of longest running non-weapons programs at LANL (since 1977)
 - **The first fuel cells for transportation program**
- The current DOE HFTO program grew out of the original Los Alamos program
- **LANL has the top world-wide citation record in Fuel Cell R&D**
- Cost and durability remain the biggest barriers to commercialization
- Program focus is obtaining fundamental understanding to enable “knowledge-based innovation,” and subsequent materials and process development
- Scientists with over **200 years of experience** related to fuels cells and over 25 Ph.D.’s



LANL Enabling Breakthrough Thin Film Electrode



An electrochemically active reaction site must have reactant access to catalyst, available electronic and ionic conduction paths, and manage water

US Patents #4,876,115, #5,211,984 and #5,234,777

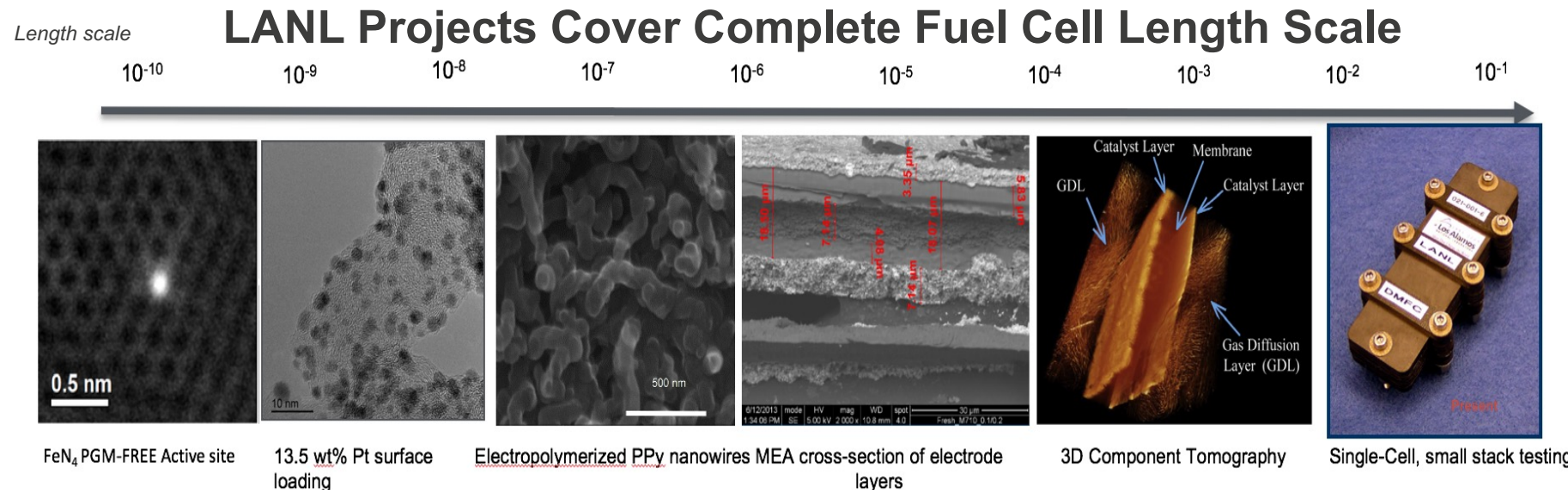


LANL's innovation in fuel cells technology has played a critical role in the technical viability of fuel cell stacks for FCEVs.

→ Every Fuel Cell Vehicle relies on technology developed at LANL

LANL Leads Fuel Cell Projects That Focus on Stack Components

- Consortia lead: M2FCT – Million Mile Fuel Cell Truck
- Consortia lead: ElectroCat – PGM-Free Electrocatalyst for Fuel Cells and Electrolyzers
- Consortia partner: H2NEW – Hydrogen production via electrolysis
 - New Catalysts: Platinum alloys and catalyst supports
 - New Membranes: non-fluorinated membranes, Alkaline membranes, high temperature membranes
 - Durability, ASTs, Characterization, Water Transport
 - Electrode Design
 - Other components: GDLs/MPLs (Gas Diffusion Layers/Microporous Layers), bipolar plates, gaskets
Hydrogen Sensors



LANL Fuel Cell Program Instrumental in NNSA Educational Programs

Inspiring thru Outreach



Florida A&M University STEM day event yielded over 1000 middle schoolers. LANL staff shows H₂/FC. (above)



University recruiting & engagements leads to more students

Inspiring the next generation with the excitement of research H₂/FC



Building on Existing Relationships

Navajo Technical University, Crownpoint New Mexico Tribal College & University

LANL has formed a long-term relationship mainly through Additive Manufacturing (MSIPP Consortia: PAMER and QCAM) Potential HFTO MSIP collaborations w/TCUs focuses on

- Establishing electrochemical capabilities to promote hybrid work
- Year round research to help better prepare students
- Developing Synergy between AM and H₂/FC research

Conferences:

- Four Corners Energy & Water Innovation Student Symposium, Farmington, NM
Special Guest: Dr. Geri Richmond, DOE Undersecretary for Science and Innovation
Ms. Tanya Trujillo, Department of the Interior Assistant Secretary for Water and Science
- Arizona Student Energy Conference
Keynote Speaker, Shalanda Baker (Director of the Office of Economic Impact and Diversity and Secretarial Advisor on Equity) Tempe, Az



3D Printing of Guillotine to Produce Precise Components for Electrochemical Systems

Wynona Wilson and Joel Yazzie
Navajo Technical University & Los Alamos National Laboratory

Overview

A fuel cell stack is an electrochemical system that produces power from chemical reactions. It generates electricity in the form of direct current (DC) from these electrochemical reactions. In fuel cell stacks it is important to isolate individual cells. Particularly, the bolts that are used to secure the stacks. Here we propose manufacturing a 3D printed guillotine that is versatile to accommodate varying tube diameters and lengths.

Accomplishments

Phase I: Safety
Improved safety using a sleeve to cover the blade
Single on/off switch versatile

Phase II: Versatility
Replaced orifices with Diamond shape
Added length control

Phase III: Verification
Used Diamond shape for final product.

Future Work

- How accurate are cuts from this device?
- Funding sources
- Can we add a scale to ensure accuracy of stopper placement for reproducibility?
- Approaches used on this project will be used towards developing new fuel cell hardware designs

Our Goal

To be able to apply these designing approaches to overcome various manufacturing challenges

Experimental Set-up

- Markforged Mark Two Onyx 3D Printer
- Material Used: Onyx
- Print Time: 16 mins - 5 hours
- Support material removal post processing

Acknowledgements

- NTU & LANL
- Funding Sources:
 - NNSA Minority Serving Institutions Partnership Program
 - DOE Hydrogen Fuel Technologies Office MSIP
 - LANL Underrepresented Minority Partnership Program

Multi-Material AM to Fabricate Bi-Polar Plates (BPP) for Electrochemical Systems

Deirdra Deswood & Winter Morgan
Navajo Technical University & Los Alamos National Laboratory

Overview

Bi-polar plates provide electrical conduction between cells and physical strength to the fuel cell stack. Direct Energy Deposition (DED) uses a laser, electron beam or plasma/electric arc as a heat source to melt metal powder through nozzles or wire feeding directly at a point on the substrate. Can we use DED to fabricate metal BPPs?

Equipment

(a) Particle Size Analyzer...
(b) Keyence VHX 6000 3D Microscope.
(c) Optomec® MTS 500 hybrid (DED)

Accomplishments

Powder Analysis
Batch 1
4 samples of 10.8 g of Ti64-123
of particles tested: 43,547
Diameter: (D₅₀ = 45 μm) & (D₉₀ = 150 μm) 99.42%
Sphericity: sphericity = 0.66, 24%

3D Microscope
Before
Sample 7A before and after grinding and polishing. Although different Magnification were used before and after voids were visible in sample.

DED Results
Ti64-123 was able to Adhere to stainless steel Substrate from 275W to 325W. Hatch spacing: 0.15 in/min. Rounds per minute (RPM): 5

Future Work

- Probe samples using microscope/XCT: porosity and surface quality
- Print a single layer SS with a single layer titanium (or titanium alloy) on top. Desired thickness < 200 microns.
- LANL to evaluate samples and compare with traditionally manufactured BPPs
- Measure corrosion properties of samples
- Investigate the addition of coatings on the sample properties

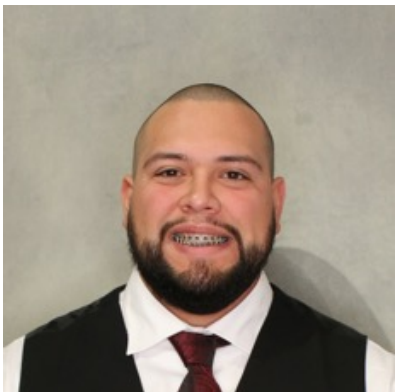
Acknowledgements

- NTU & LANL
- Funding Sources:
 - NNSA Minority Serving Institutions Partnership Program
 - DOE Hydrogen Fuel Technologies Office MSIP
 - LANL Underrepresented Minority Partnership Program

Our Goal:

To continue to learn more about energy-related research

On-campus projects Expand Opportunities



Robert Lazarin



Cortney Kreller



Rod Borup

- M.S. Mechanical Engineering (December 2022), University of Texas at El Paso
 - Thesis: ***“THE QUALIFICATION OF SEALABILITY AND CREEP RELAXATION OF ADDITIVELY MANUFACTURED ZYTEL GASKETS FOR PEM FUEL CELLS”***
 - Focus: Hydrogen Fuel Cells, Gaskets, Leak Rate, Creep Relaxation, Additive Manufacturing

Began Collaborating

Graduated M.S. in ME in fall 2022



Graduate Internship

- Post-master's student at LANL (January 2023)
- Three focus areas: High Pressure PEMFC Gaskets, Electrochemical Corrosion of Metals, Novel Catalyst Manufacturing for PEMFC's

Development of High Pressure FC Gaskets



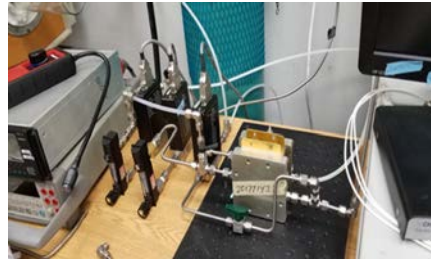
Electrochemical Corrosion of Metals

Manufacturing Techniques for PEFC Electrodes





Collaboration and Coordination: Industry



David Yapell

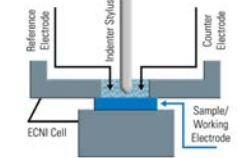
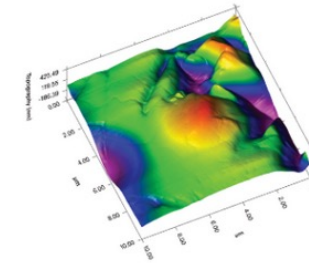
PhD Thesis: :
Experimentation of Corrosion in PEM Fuel Cell Environment with Machine Learning based modeling



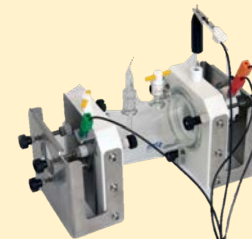
- B.S. Computer Engineering (2020), Florida International University(FIU)
 - Research in wearable bio-electrochemical/solid state sensors for hormone detection in sweat
- M.S. Computer Engineering (2021), FIU
 - Design, Fabrication and Characterization of Fuel Cell Membranes, Electrodes and Bipolar Plates in collaboration with LANL
- PhD Computer Engineering (2024 expected), FIU
- Focus: Electrochemistry, Corrosion, Sensors, Machine Learning

- Graduate Research Assistant beginning May 2022
- Current projects:
 - PhD thesis on corrosion detection and modeling
 - Development of an AST for Coated Metal Corrosion Testing
 - Metal Corrosion and Modeling

Treadstone - Coated Metal Corrosion and AST Development



GM – Metal Corrosion and Modeling



Collaboration and Coordination: LANL-Industry

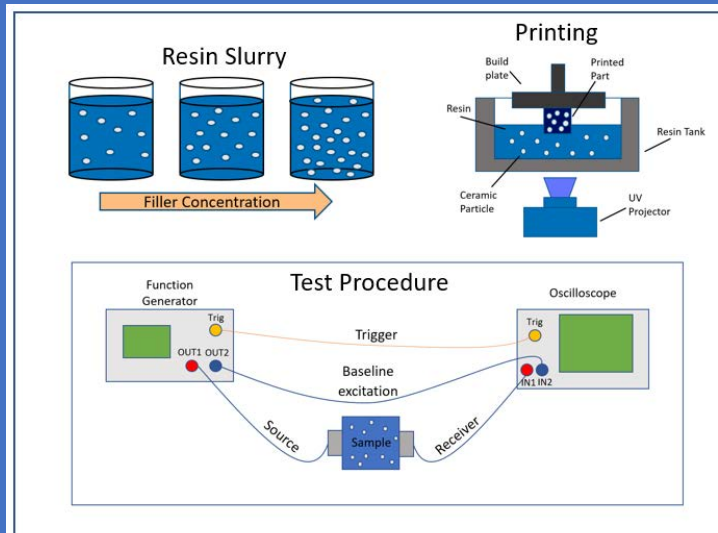


Visit to PP facility allowed release of novel catalyst for testing

- B.S. in Mechanical Engineering (Fall 2021), University of Texas at El Paso
- M.S. in Mechanical Engineering (Anticipated Summer 2023), University of Texas at El Paso
- Graduate research assistant at Los Alamos National Lab



Ultrasonic Non Destructive Evaluation of Additively Manufactured Polymer-Ceramic Parts



Parameterization and characterization of slot die coater procedure and ink formulation for fuel cell applications

Collaboration and Coordination: Industry



CA²REERS CONSORTIUM

Advanced Additive Manufacturing Research and Education for Energy Related Systems

Consortium of Advanced Additive Manufacturing Research and Education for Energy Related Systems (CA²REERS)



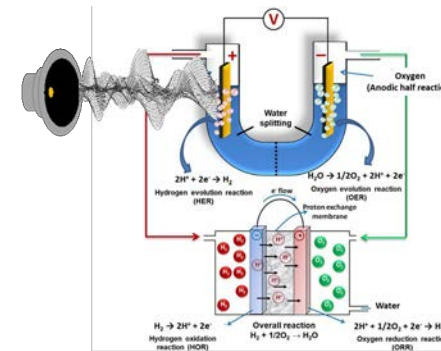
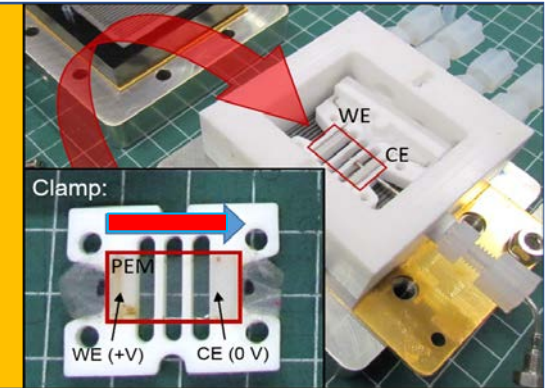
Welcome to the Consortium of Advanced Additive Manufacturing Research and Education for Energy Related Systems.

Lyra Troy

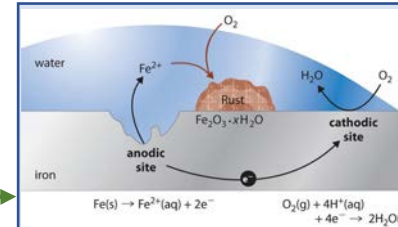
- M.S. Chemical Engineering (2022), University of Arizona
 - Thesis: *“Stability of metal-metal ion secondary reference electrodes in molten salt”*
 - Focus: **Electrochemistry, Chemical Engineering concepts**

- Post-master's student at LANL (October 2022)
- Three projects: GM Membrane Degradation, Nickel OER using acoustics, Corrosion of metals

Collaboration with GM - Membrane Degradation project



Enhancing OER performance using novel techniques



<https://www.electrochem.org/corrosion-science/>

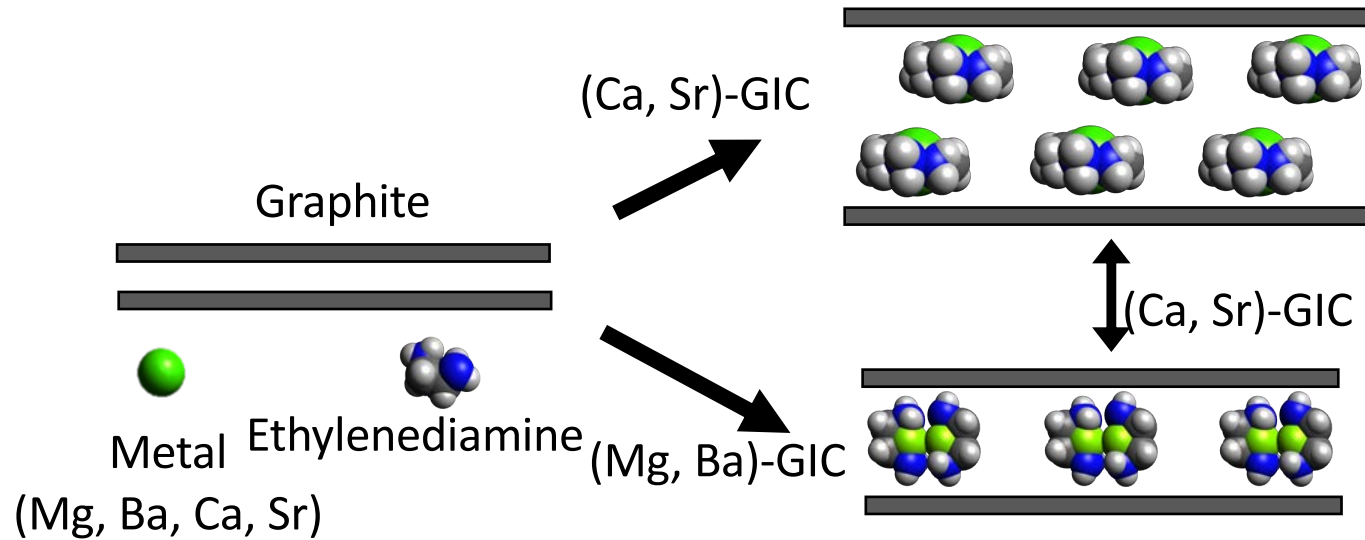
Corrosion studies: Experimental and Modeling



Collaboration and Coordination: LANL-MSIs

Investigating Hydrogen Storage Materials

- Univ of Texas-Rio Grande Valley,
(Rigobert Ybarra and Matthew Salinas)
- Professor Macossay , Visiting Faculty Guest
- New storage materials are needed to achieve that goal



Daniel Leonard, LANL Staff



Students synthesize materials at UTRGV
Then come to LANL to test characteristics

Collaboration and Coordination: LANL-MSIs

- University of Texas-Rio Grande Valley: Marina Pacheco
- Water electrolysis is a promising electrochemical energy storage technology to produce green hydrogen
- High mechanical stability is critical for membranes used in water electrolyzers
- Fabrication of reinforced membranes to demonstrate enhanced mechanical properties



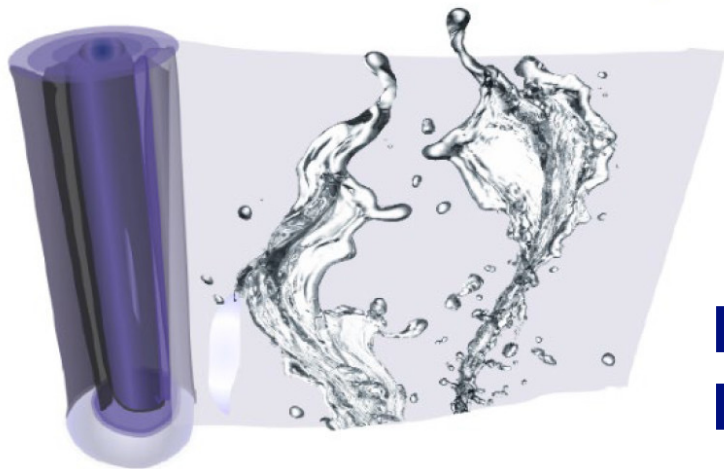
Sarah EJ Park, LANL staff



Marina Pacheco

Macossay Research Group

Membranes for water electrolysis



Engaging MSIs: Developing Mechanically Enhanced Reinforced Membranes



Thank you for participating!

A recording of this seminar will be available
on the Events page of the I-WEST website

www.iwest.org