I-WEST

Seminar Series

July 19, 2023

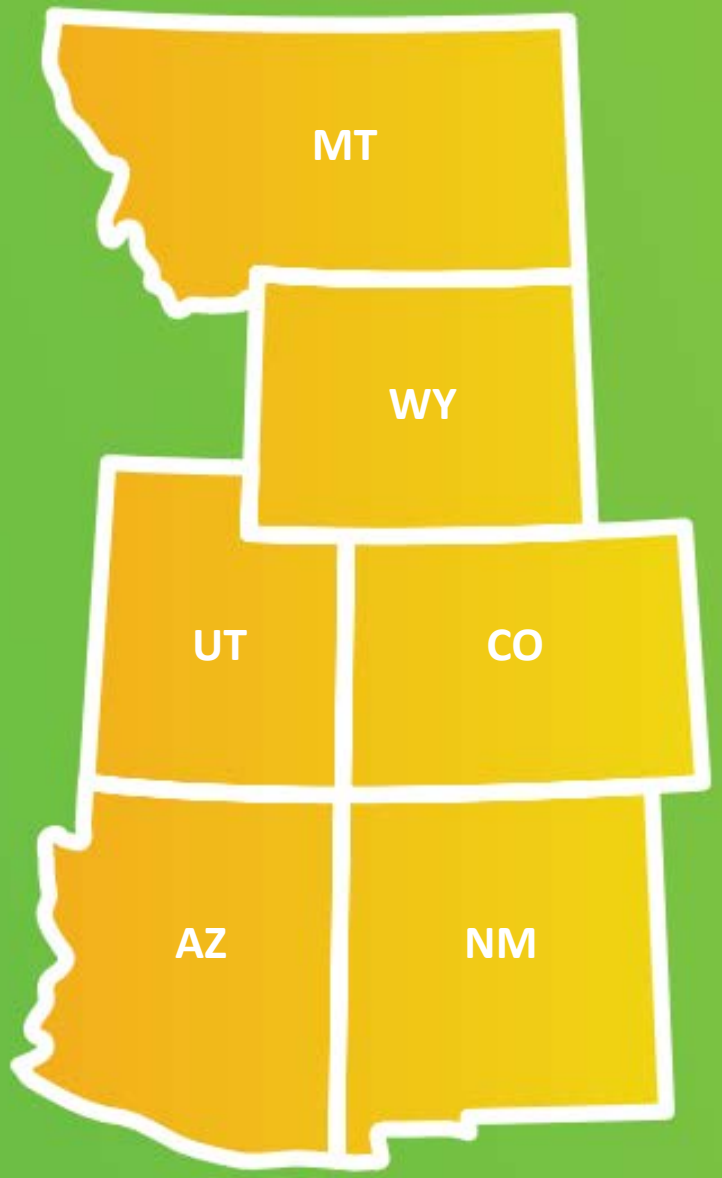
LA-UR-23-28345

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

I-WEST

TODAY'S SEMINAR

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

Los Alamos NATIONAL LABORATORY

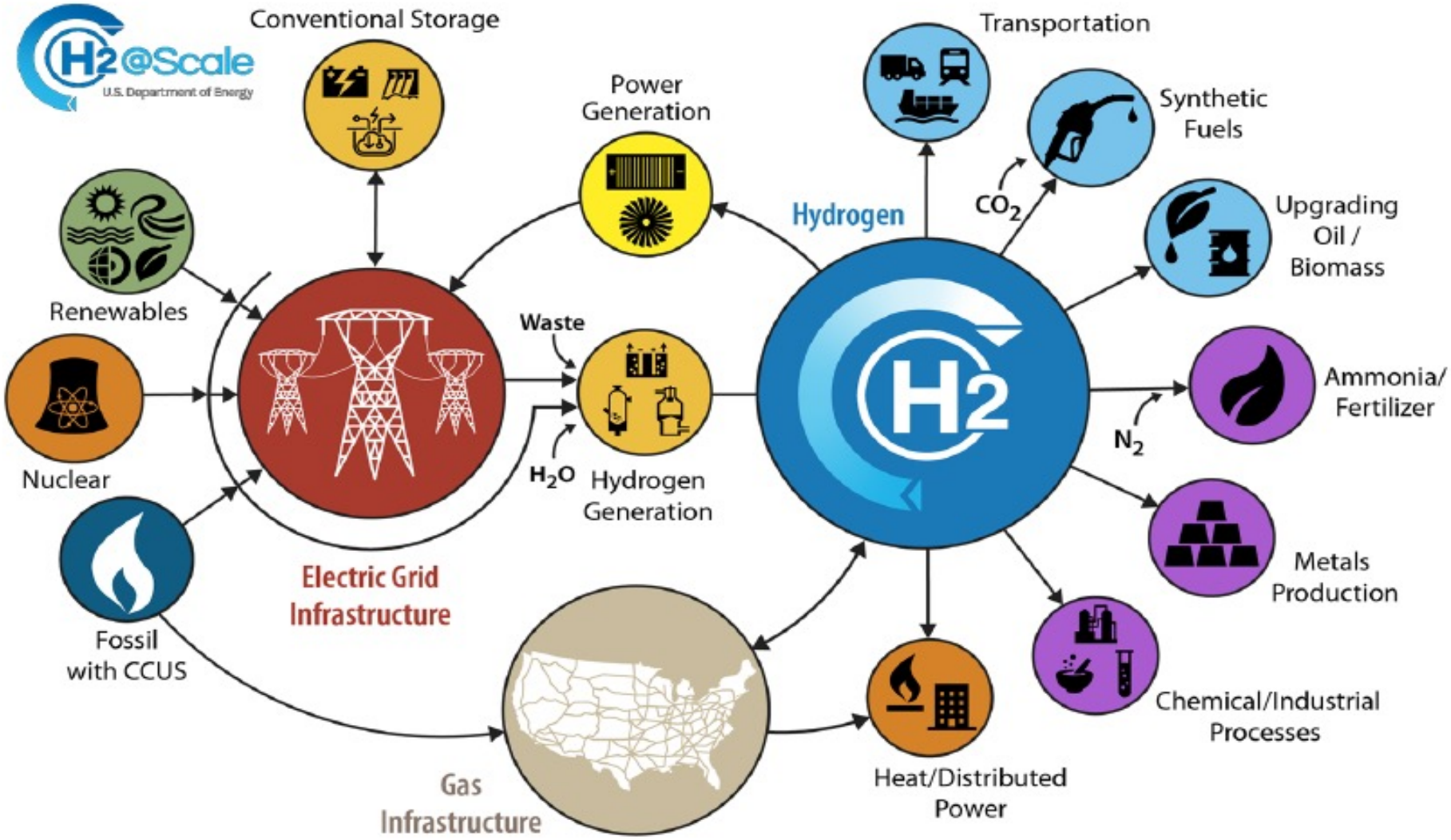
Fascinating Fuel Cells at LANL

July 19, 2023

Dr. Daniel Leonard
MPA-11

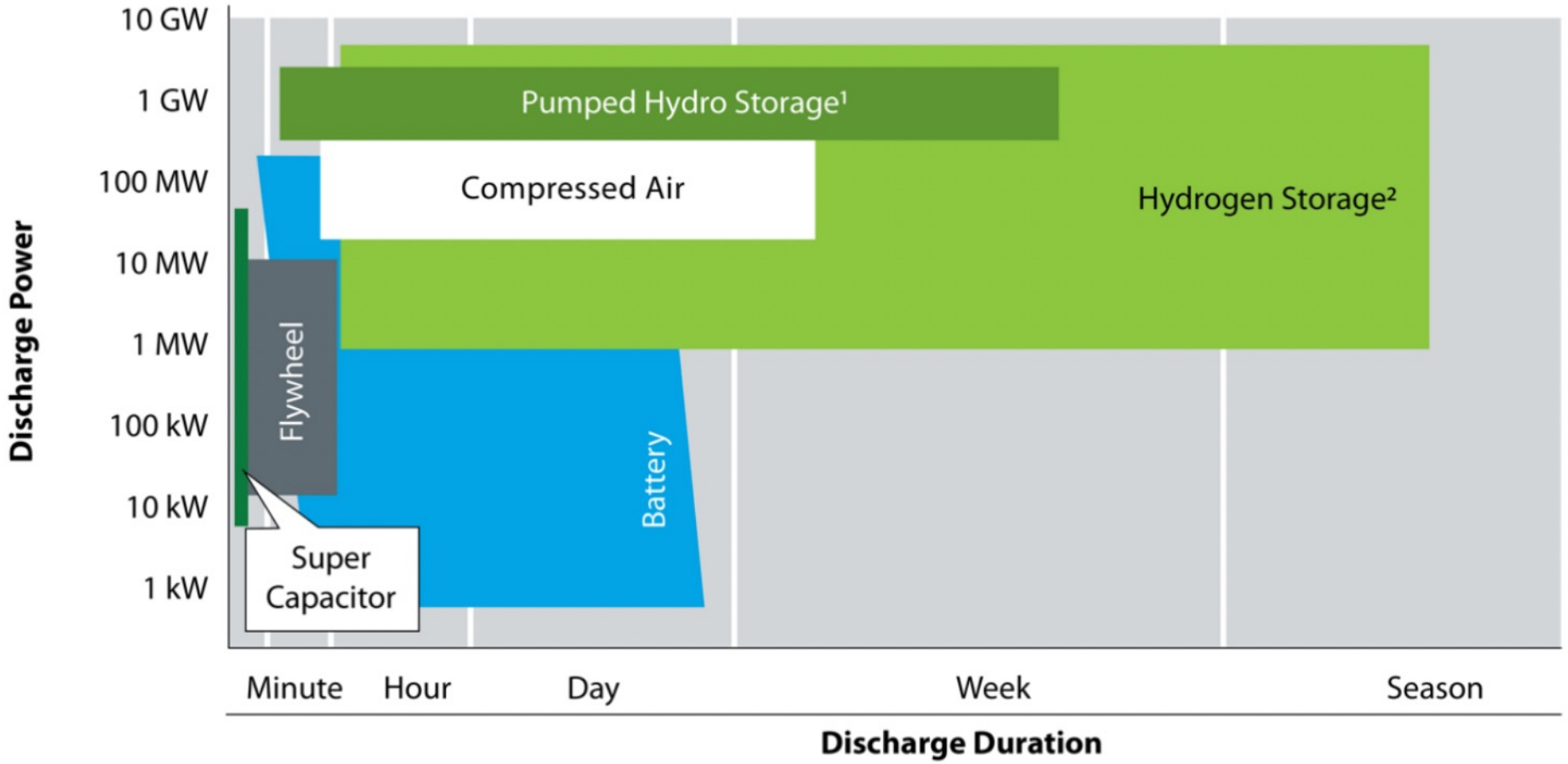
Conceptual H_2 at Scale Energy System*

Decarbonize the Three Energy Sectors Simultaneously



*Illustrative example, not comprehensive

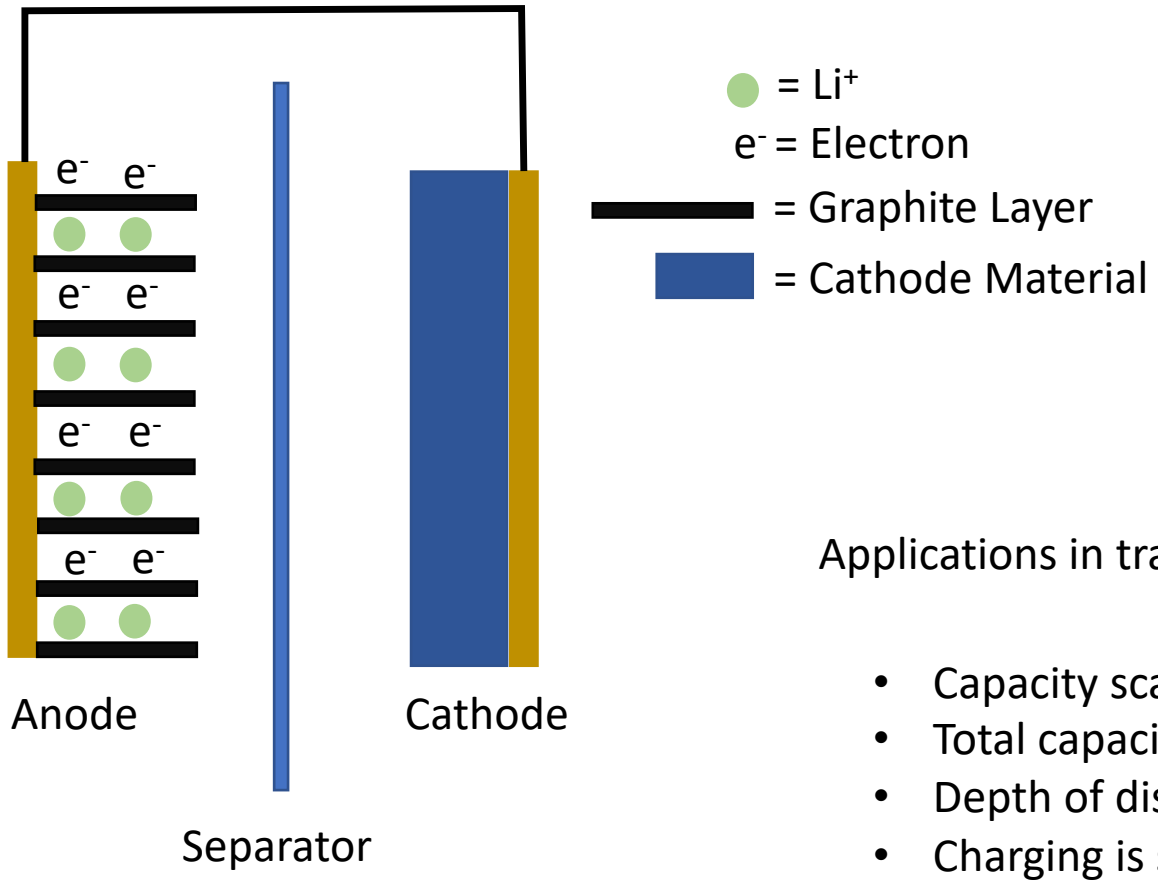
Hydrogen Potential Grid-scale Storage



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

NREL – The Technical and Economic Potential of the H2@Scale Concept within the United States, 2020

Lithium-ion Batteries



● = Li^+
e^- = Electron
= Graphite Layer
= Cathode Material

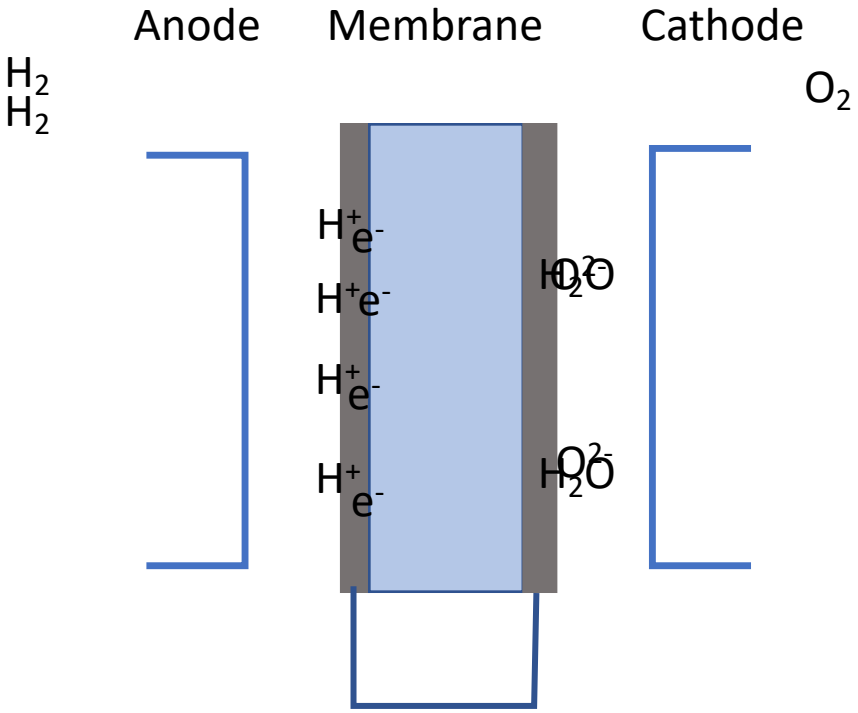
Specific Power Output
0.25-0.35 kW/kg

Efficiency
80-90%

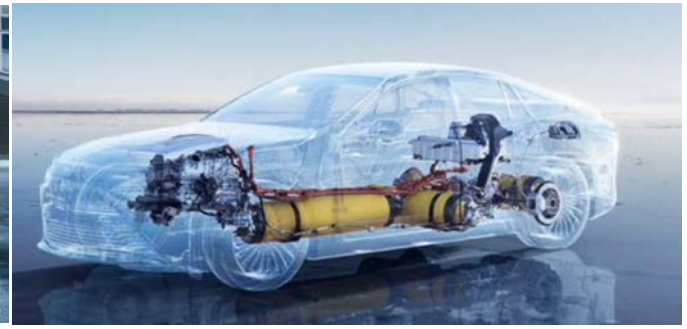
Applications in transport and short-duration energy storage (hours)

- 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



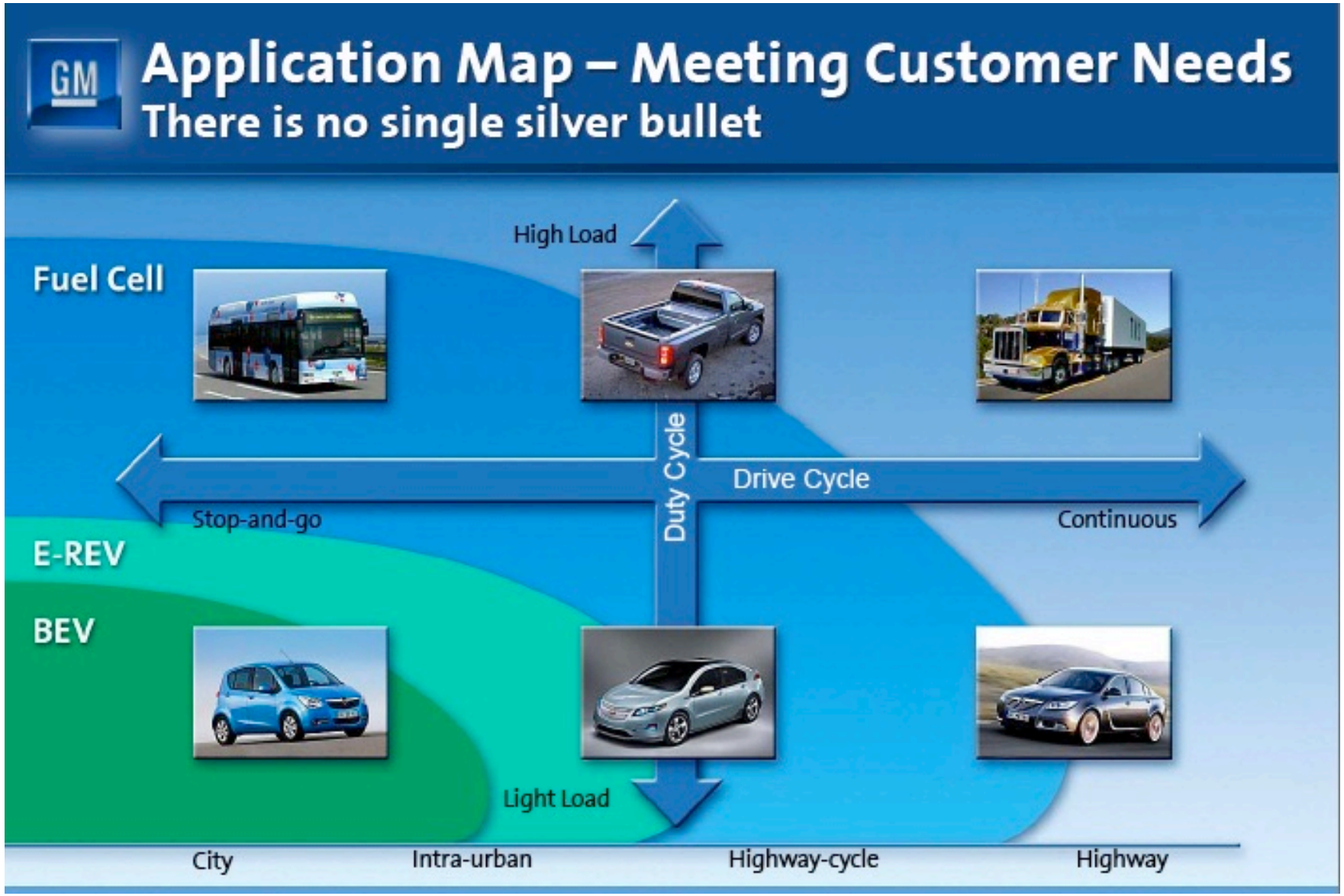
Specific Power Output
5.4 kW/kg



Efficiency
60-70%

Applications in heavy-duty transport, aviation, shipping

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

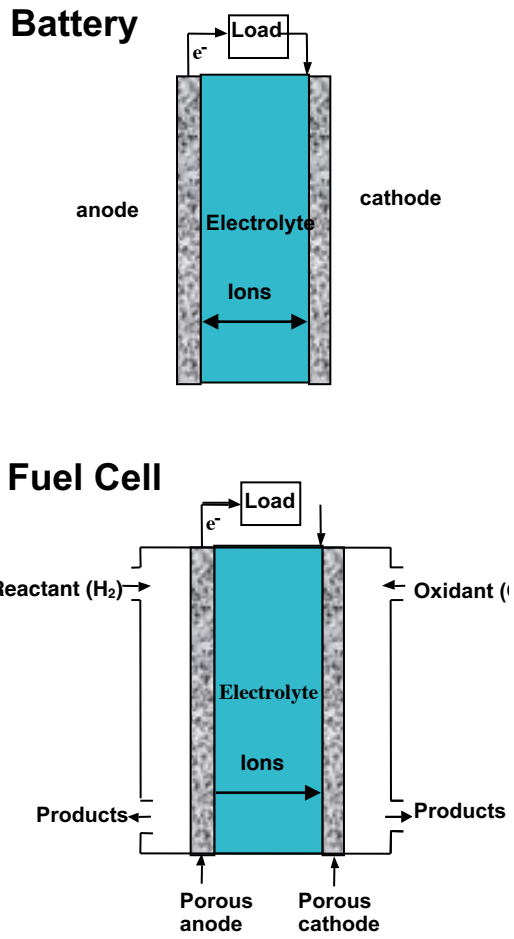
Compressed Hydrogen

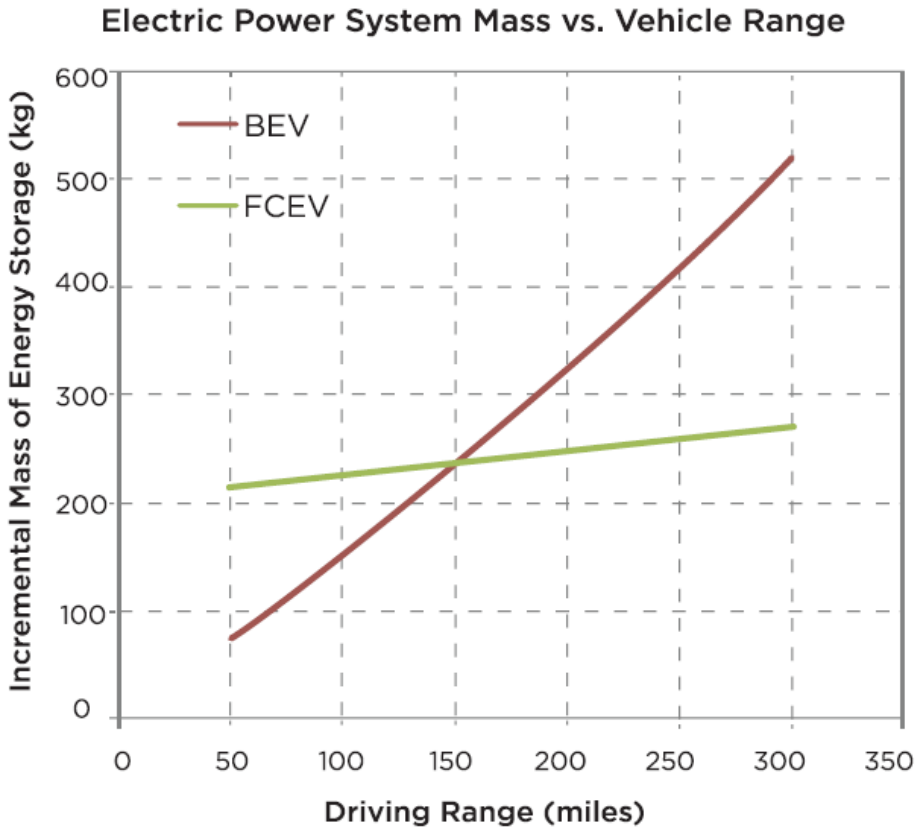
Fuel Amount:	55 kgs
Fuel Weight:	120 lbs
Tank Weight:	4,200 lbs
Total Weight:	4,320 lbs

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





Why does it take so long to charge batteries?

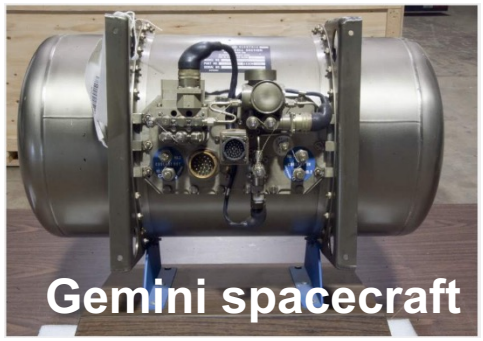
Fueling Time Analogy

- 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.

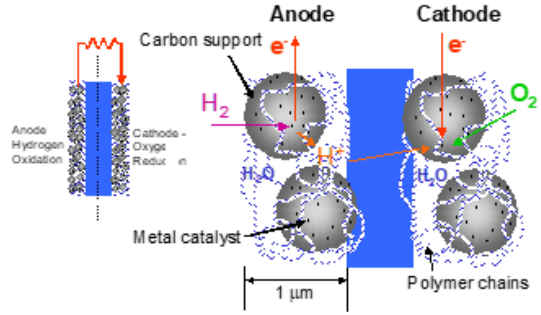
Advantages: energy density (up to >6000 Whr/kg based on fuel, batteries up to 150 Whr/kg), refuel versus recharge

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

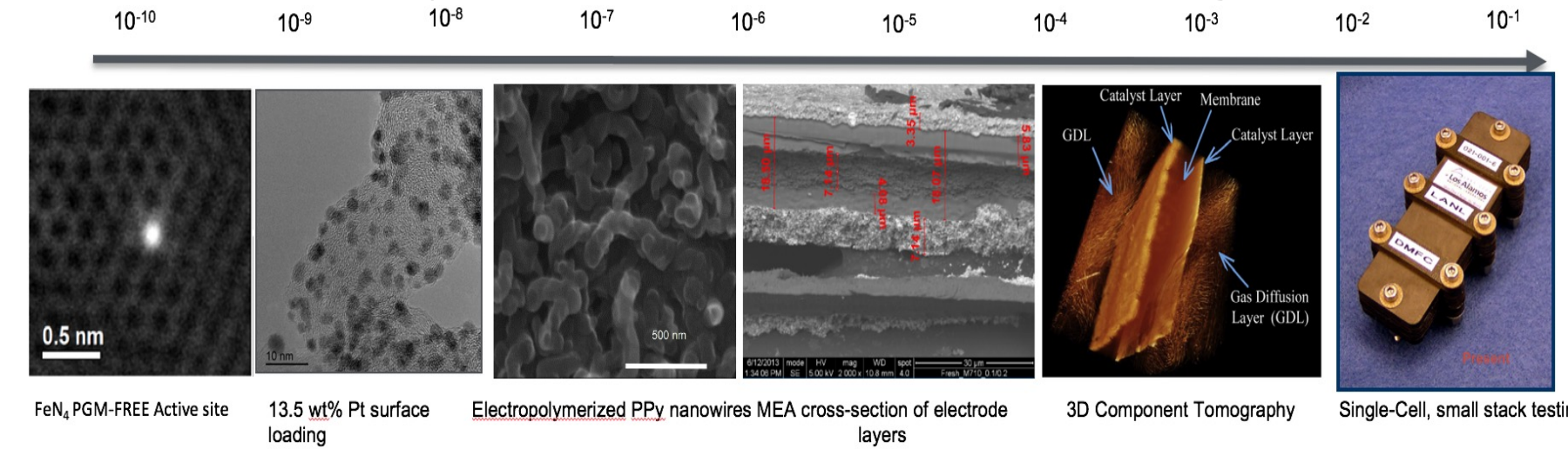
LANL's innovation in fuel cells technology has played a critical role in the technical viability of fuel cell stacks for FCEVs.

→ 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/Micropouros Layers), bipolar plates, gaskets Hydrogen Sensors*

LANL Projects Cover Complete Fuel Cell Length Scale



FeN_4 PGM-FREE Active site

13.5 wt% Pt surface loading

Electropolymerized PPy nanowires MEA cross-section of electrode layers

3D Component Tomography

Single-Cell, small stack testing

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 H_2/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 H_2/FC research

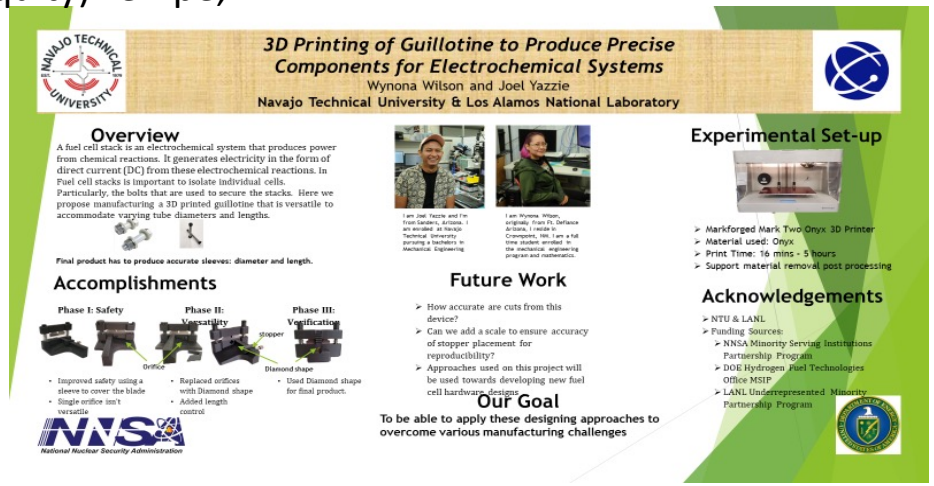
Conferences:

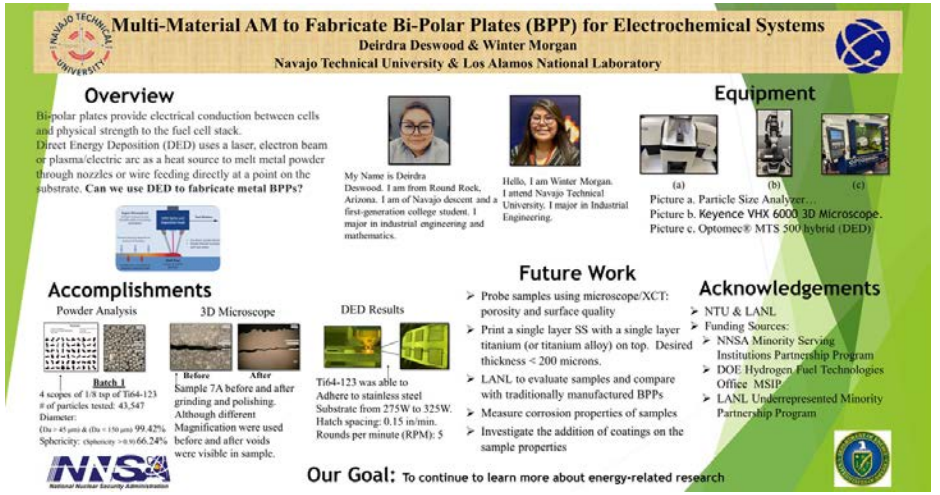
1. Four Corners Energy & Water Innovation Student Symposium, Farmington, NM

Special Guest: **Dr. Geri Richmond,** DOE Undersecretary for Science and Innovation
Ms. Tanya Trujillo, Department of the Interior Assistant Secretary for Water and Science

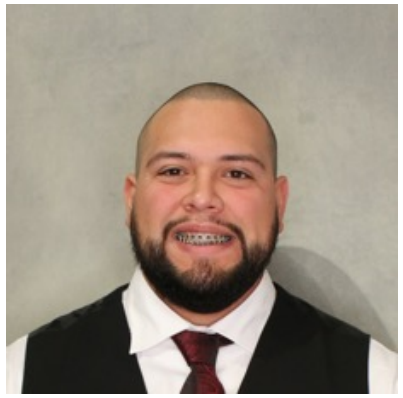
2. Arizona Student Energy Conference

Keynote Speaker, **Shalanda Baker** (Director of the Office of Economic Impact and Diversity and Secretarial Advisor on Equity) Tempe, Az



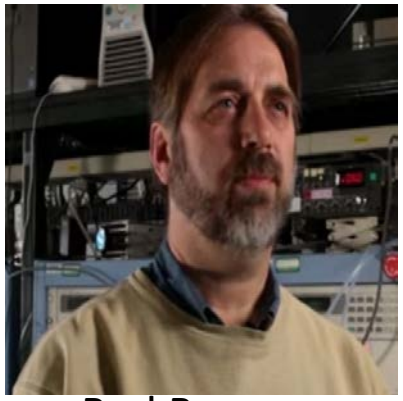


On-campus projects Expand Opportunities



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 202

Los Alamos NATIONAL LABORATORY

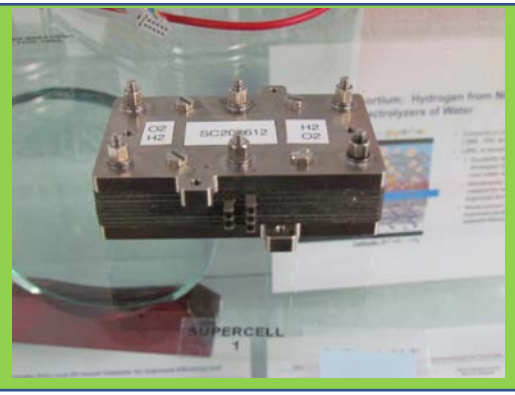
Fall 2020 → Summer 2021 → Summer 2022 → Post Master's

PRE CCAP

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

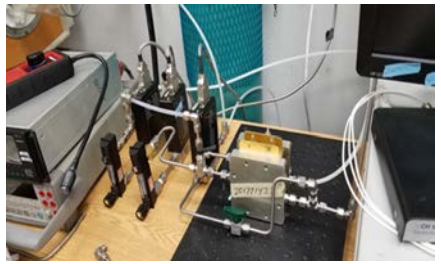
Development of High Pressure FC Gaskets



Electrochemical Corrosion of Metals

Manufacturing Techniques for PEFC Electrodes

Collaboration and Coordination: Industry



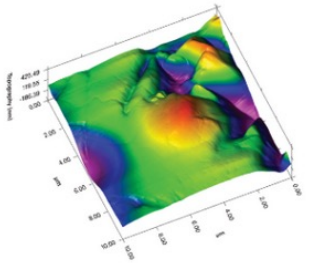
David Yapell

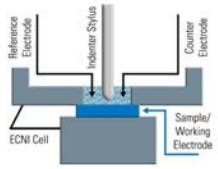
- B.S. Computer Engineering (2020), Florida International University(FIU)
  - Research in wearable bio-electrochemical/solid state sensors for hormone detection in sweat
- M.S. Computer Engineering (2021), FIU
  - Design, Fabrication and Characterization of Fuel Cell Membranes, Electrodes and Bipolar 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

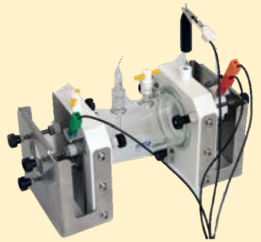
PhD Thesis: :
Experimentation of Corrosion in PEM Fuel Cell Environment with Machine Learning based modeling

Treadstone - Coated Metal Corrosion and AST Development





GM – Metal Corrosion and Modeling



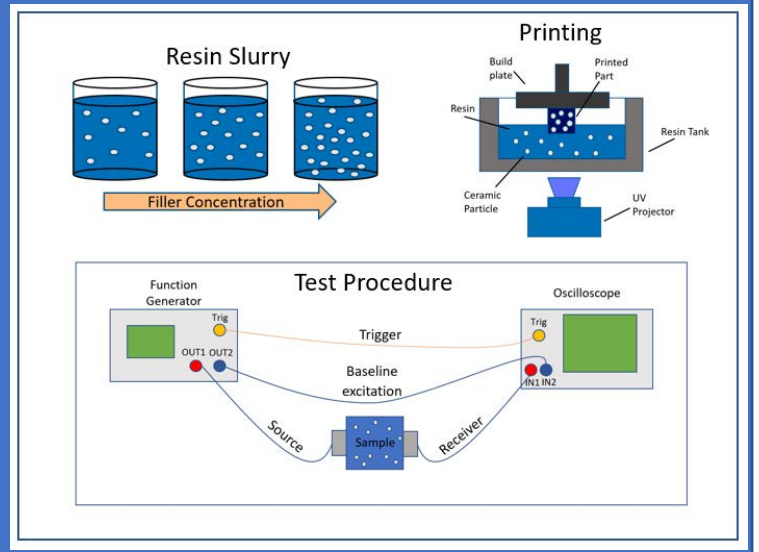
Collaboration and Coordination: LANL-Industry

PAJARITO POWDER
FUEL CELL CATALYSTS

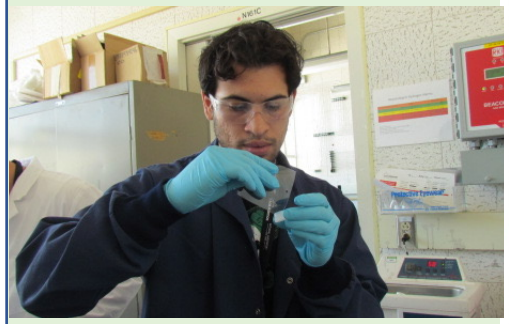
- B.S. in Mechanical Engineering (Fall 2021), University of Texas at El Paso
- M.S. in Mechanical Engineering (Anticipated Summer 2023), University of Texas at El Paso
- Graduate research assistant at Los Alamos National Lab

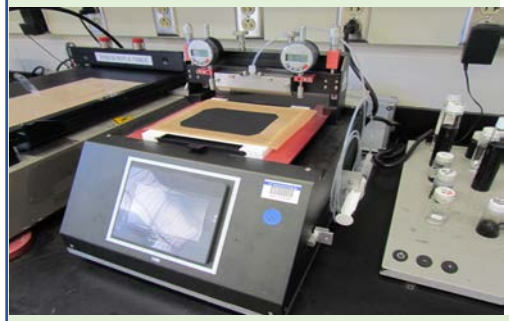
PRE CCAP
Partnership for Research and Education
Consortium in Ceramics and Polymers

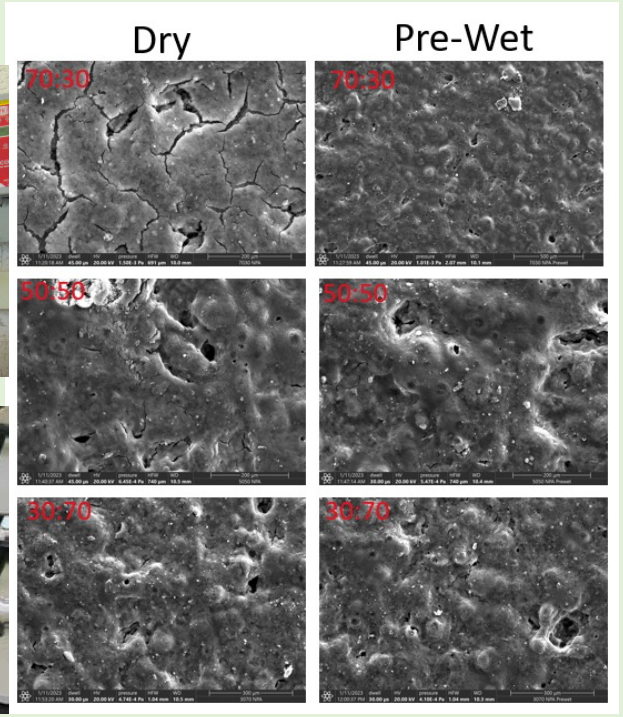
Ultrasonic Non Destructive Evaluation of Additively Manufactured Polymer-Ceramic Parts



Visit to PP facility allowed release of novel catalyst for testing







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

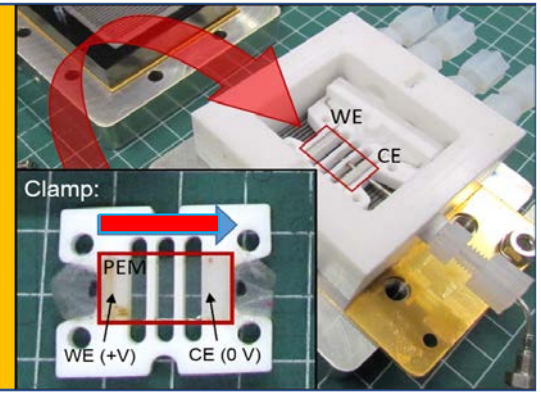
Collaboration and Coordination: Industry

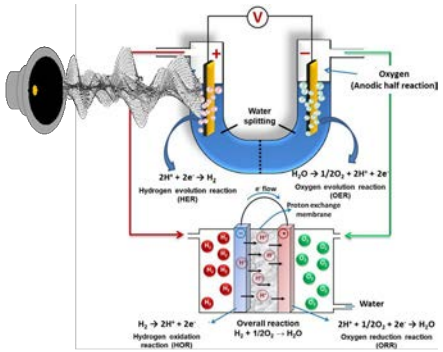
Lyra Troy

- 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**

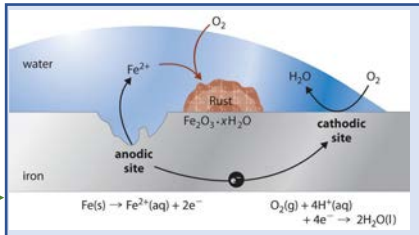
- Post-master's student at LANL (October 2022)
- Three projects: GM Membrane Degradation, Nickel OER using acoustics, Corrosion of metals

Collaboration with GM - Membrane Degradation project





Enhancing OER performance using novel techniques



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

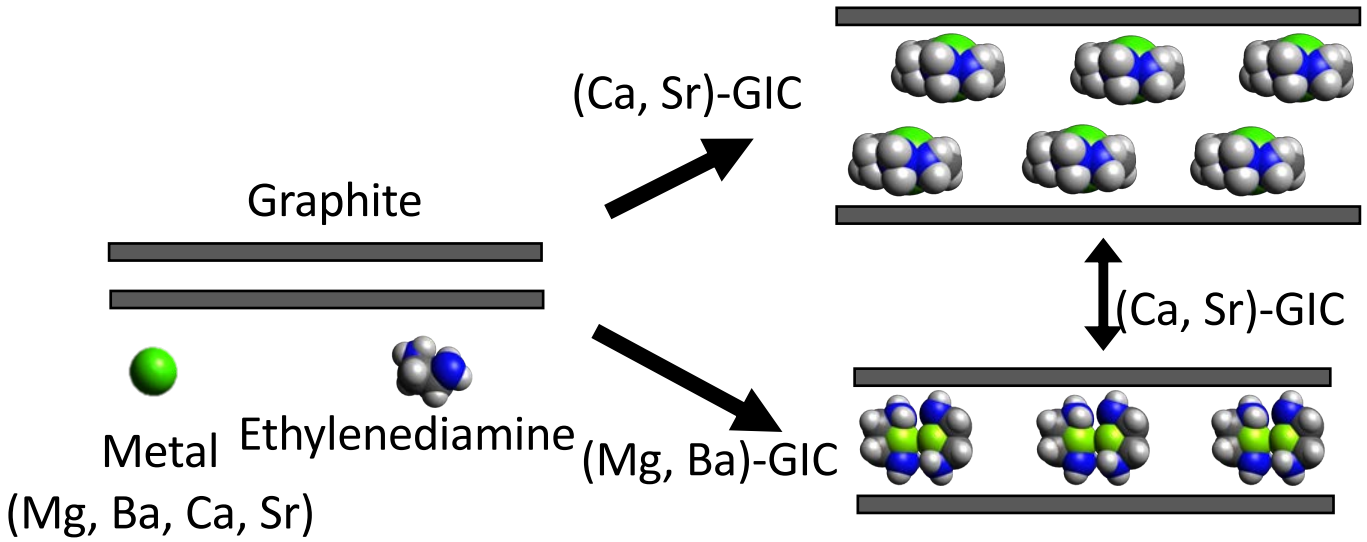
Corrosion studies: Experimental and Modeling

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

Engaging MSIs: Developing Mechanically Enhanced Reinforced Membranes

I-WEST

Thank you for participating!

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

www.iwest.org