“How System Integrators Can Help Accelerate the Adoption of Advanced Materials”

Colorado State University Materials Science & Engineering 2026 Symposium

March 6th, 2026

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What is a System Integrator?
Engineers applying fundamental research

- Combines hardware (including advanced materials), software, controls into a complete, working solution
- Develop new components & systems with advanced materials
- Ensures subsystems work together reliably
- Translates customer needs into functional, engineered systems
- Solve complex challenges while ensuring safety & performance

How do System Integrators Collaborate to Help Make Material Discovery Meaningful?

ARPA-E catchphrase:

*If it **Works**,*
*will it **Matter?***

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Why Many Great Materials Never Reach the Market

The "Lab-to-Market Gap"

- **Manufacturing** – Hard or costly to scale; inconsistent properties; needs specialized processing
- **Integration** – Compatibility with existing systems; may require redesign of components
- **Cost & Supply** – Rare/expensive materials; immature processes; cheaper alternatives exist
- **Reliability** – Limited long-term data; unknown failure modes; industries demand proven durability
- **Certification** – Lengthy testing and approval cycles in aerospace, energy, medical sectors
- **System Economics** – Material benefits must outweigh integration costs and operational risks

The most important engineering breakthroughs often happen at the **intersection of disciplines**

Materials enable the technology, but **systems engineering makes it work in the real world**

How System Integrators Help Accelerate the Adoption of Advanced Materials

Bridge Between Research and Real Systems

- Translate lab-developed materials into deployable systems
- Identify where advanced materials improve performance

System-Level Evaluation

- Test materials under full operating conditions: temperature, stress, corrosion, electrical loads
- Ensure compatibility with existing components and infrastructure

Reduce Technology Risk

- Build prototypes and pilot systems
- Validate materials in real conditions and identify failure modes early

Enable Cross-Disciplinary Integration

- Combine materials innovations with mechanical design, electronics, thermal management, and manufacturing

Accelerate Commercialization

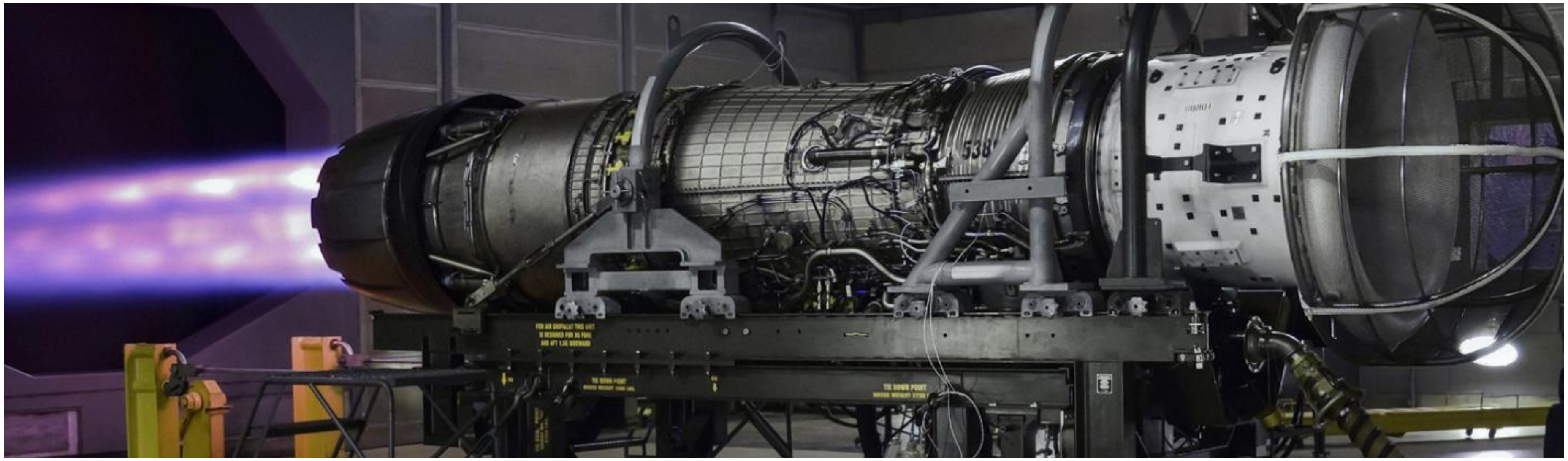
- Turn promising materials into products and industrial systems
- Support scaling from prototype → pilot → commercial deployment

The Turbine Blade That Should Melt — But Doesn’t

The Surprising Fact

- In modern jet engines, the combustion gas temperature can exceed **1,600–1,800°C**
- But the turbine blades are made from metals that melt around **~1,300–1,400°C**.

So why don’t they melt?



It Works Because Multiple Technologies Are Integrated:

Advanced Materials - *Material Science*

- Nickel Superalloys maintain strength at extreme temperatures
- Thermal Barrier Coatings protect the metal surface
- Single-Crystal Turbine Blade Casting eliminates grain boundaries

Internal Cooling – *System Design/Integration*

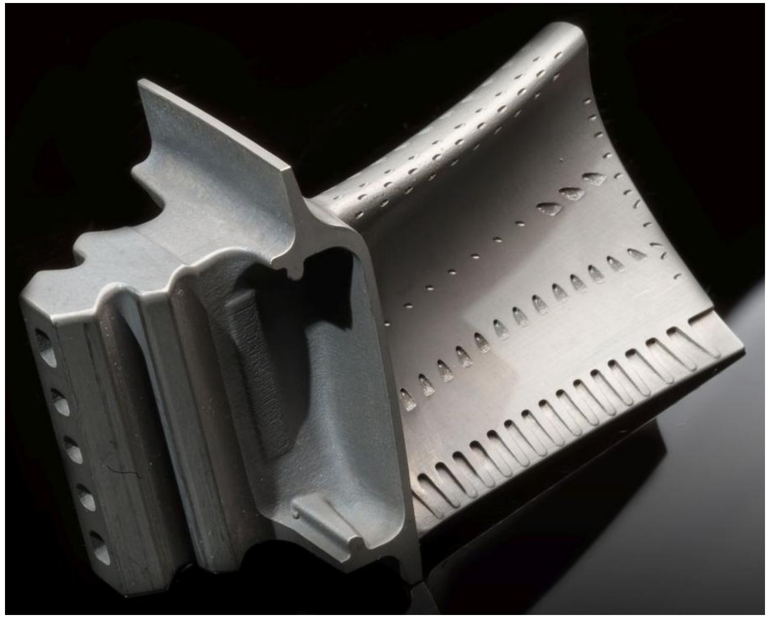
- Turbine blades contain tiny internal cooling channels
- Compressed air flows through the blade
- This keeps the metal hundreds of degrees cooler than the gas

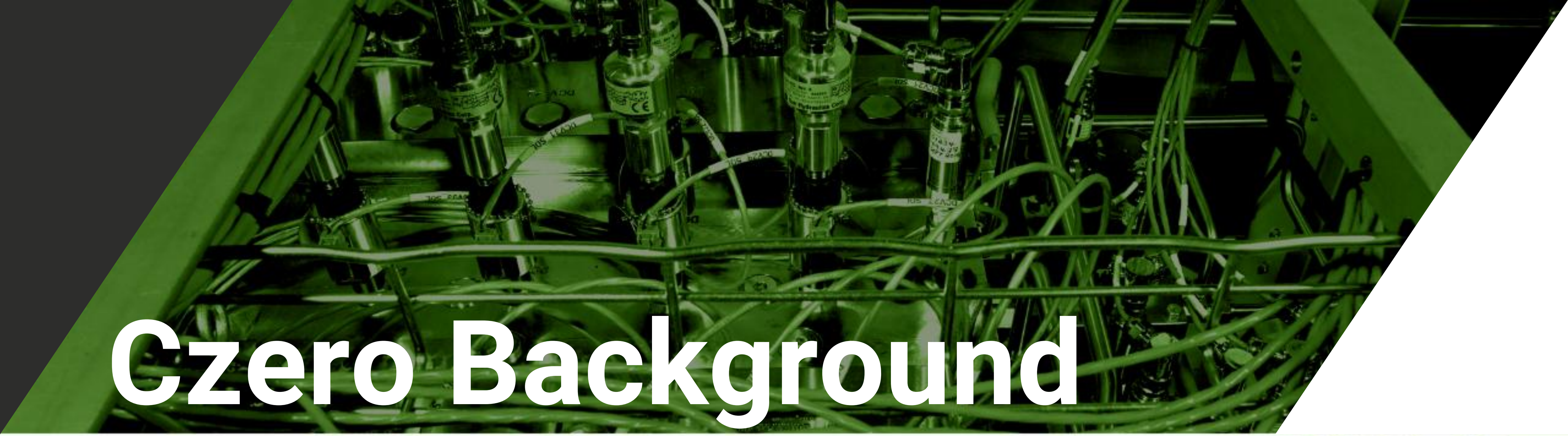
Aerodynamic Design and Analysis – *System Design/Integration*

- Computational Fluid Dynamics (CFD) to optimize mechanical loads
- This keeps mechanical loads within acceptable bounds

System-Level Design – *System Design/Integration*

- Combustor temperature control
- Cooling airflow management
- Advanced turbine aerodynamics



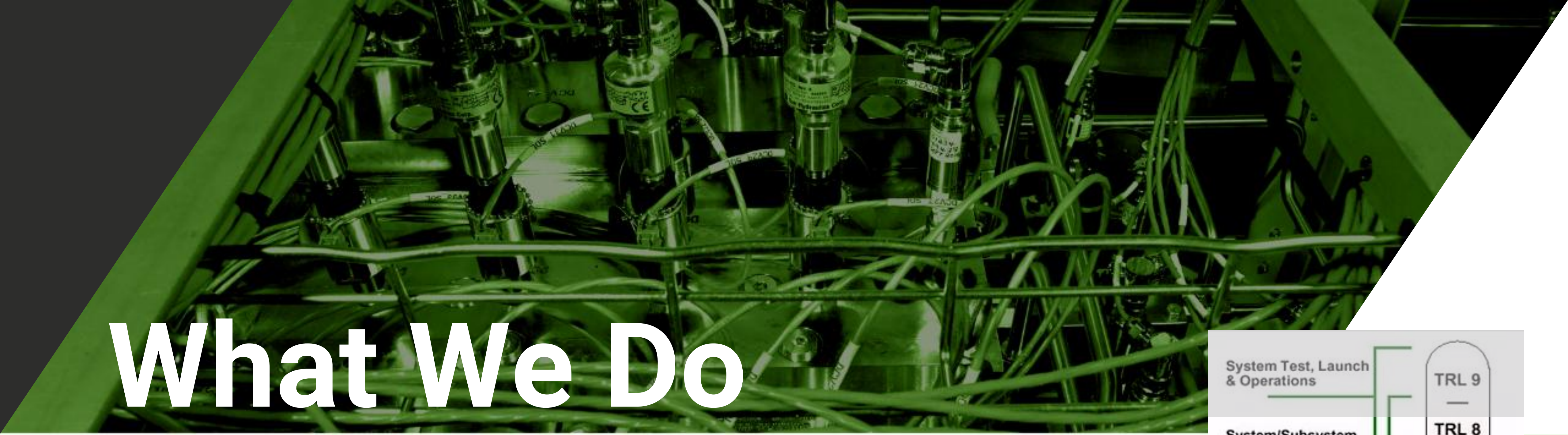


Czero Background

Czero innovates, designs, and advances technologies for energy conversion, use, and storage.

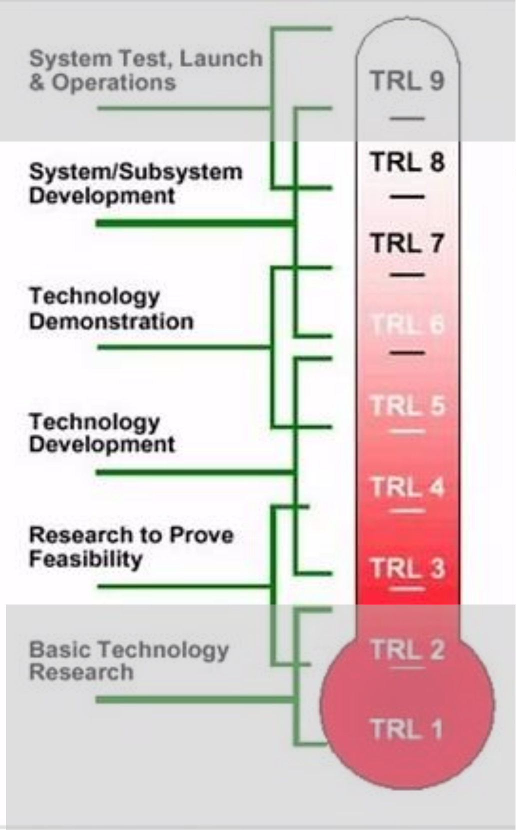
Stats:

- 19-year-old firm founded in 2007
- Located in Fort Collins, CO
- Clients: DOE, DOD, National Labs, Universities, and companies of all sizes
- Primarily contract R&D/engineering services/System Integration
- Technology agnostic – work on all sources of energy production, storage, conversion and use
- 16,000 ft^2 facility w/prototype build and test facilities: material receiving & handling, In-house machine shop, metrology, control panel build shop, and other critical operational infrastructure to deliver prototypes
- Test capabilities include: Hydrogen test cell, electric engine dynamometer, thermal chamber, high power hydraulics, HIL setup, etc.
- Czero's network includes suppliers with deep expertise in advanced fabrication and manufacturing capabilities such as additive manufacturing, material joining, machining, and other state-of-the-art manufacturing processes
- More than 450 projects completed



What We Do

Czero helps other companies and organizations develop innovative hardtech technologies in the energy space. *Typically, low TRL*



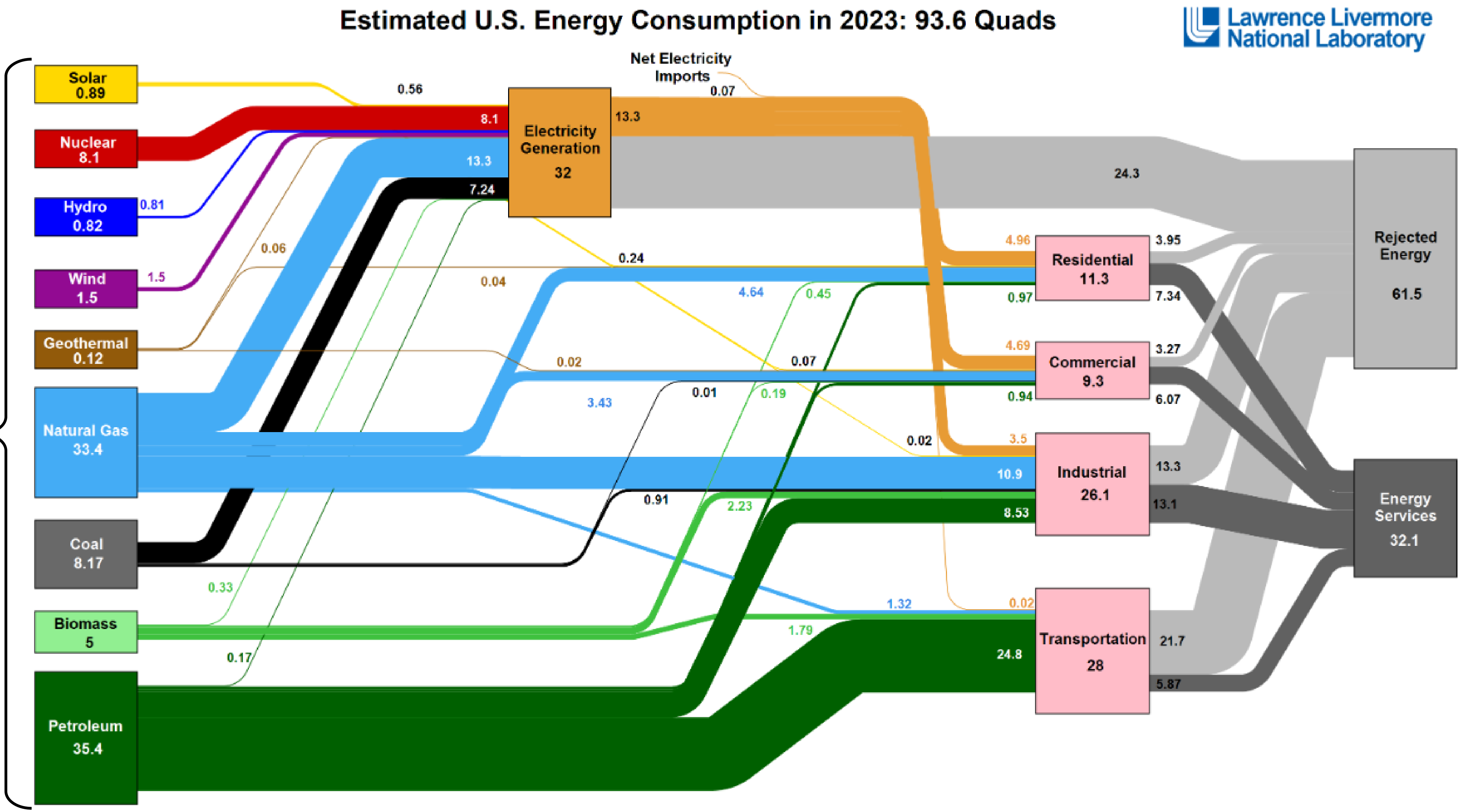
Technology Readiness Levels

Core Expertise – Complex System Integration

- We focus on early-stage technologies in the energy space
- Can do entire projects from napkin sketch to robust prototype systems or do a discrete part of a project

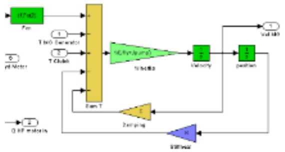
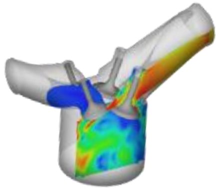
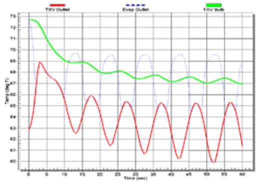
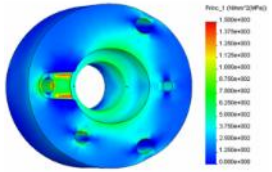
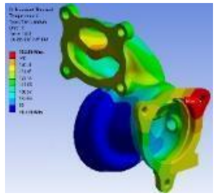
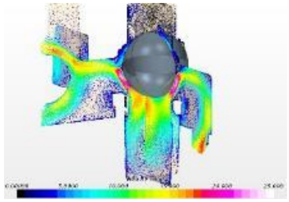
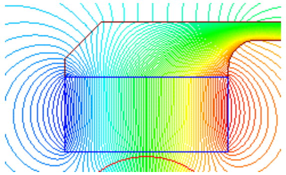
Czero is Technology Agnostic

Czero has been involved in helping develop technologies for every energy source listed here except coal

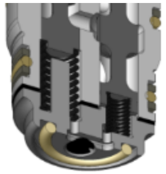
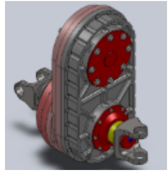
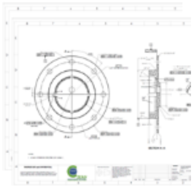
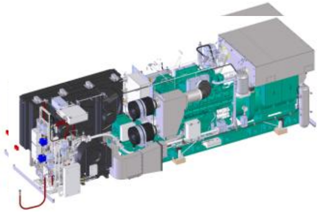
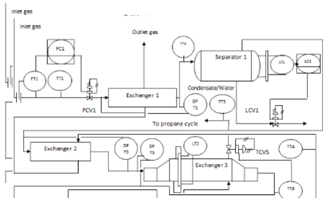
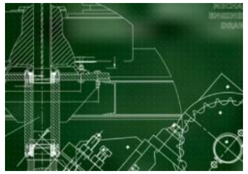


Three Groups – All Highly Integrated

Modeling & Simulation – Dynamic modeling, thermodynamic analysis, FEA, CFD, magnetic modeling

Mechanical Design – Solid Modeling, GD&T, System design, layout studies, tolerance stacks, etc. Process flow diagrams


Controls - Embedded controls, rapid prototyping systems, industrial automation, HIL, MIL, SIL systems, advanced controls algorithm development (dynamic programming, non-linear, optimal, and adaptive control, neural networks)

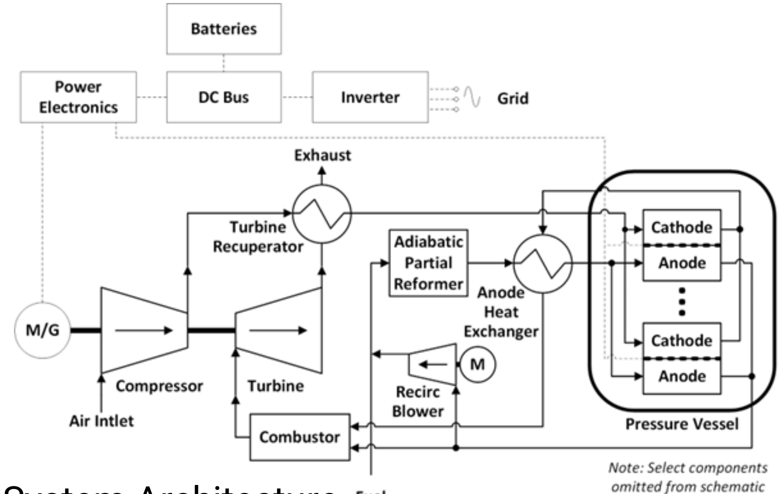



Example Projects

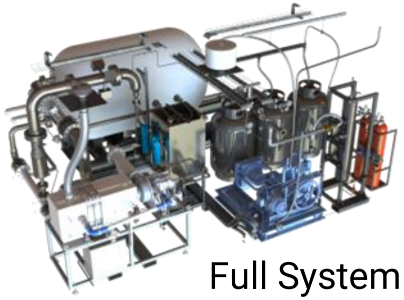
Solid Oxide Fuel Cell/ Gas Turbine Hybrid System

Quick Project Facts:

- 70%+ efficiency @ 50 kWe
- Natural gas fueled
- Pressurized operation
- Operating temperatures:
  - 850°C (SOFC), 930°C (GT)
- Turbine speed: 90,000 rpm

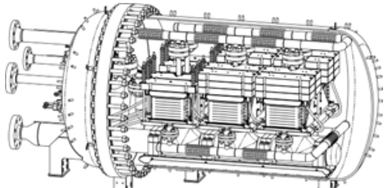


System Architecture

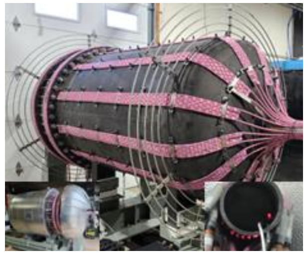


Full System Layout

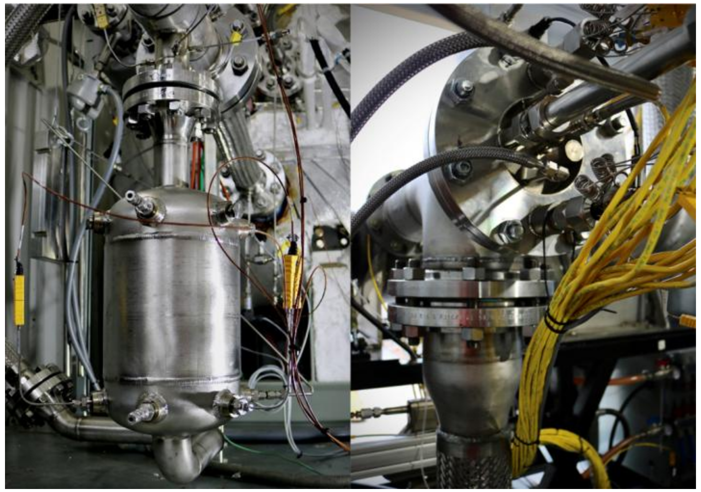
SOFC/GT Test Cell

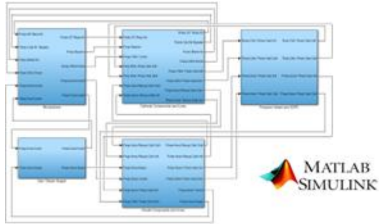


Pressure Vessel with SOFC Stacks

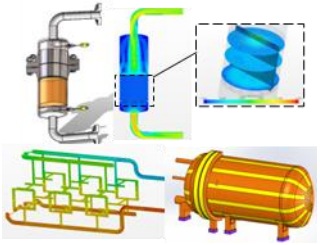


Pressure Vessel



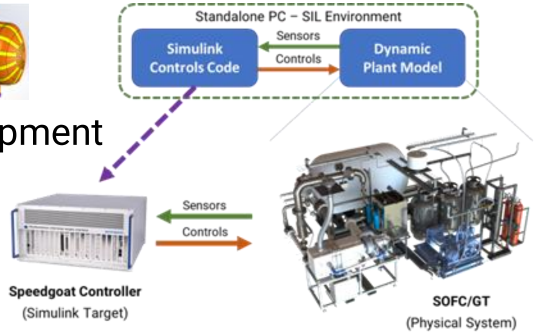


Dynamic System Modeling

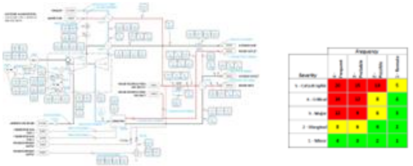


Component Development

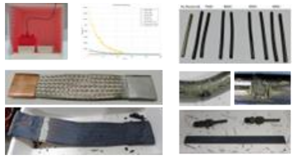
Balance of Plant



MIL/SIL Controller Development and Validation



System P&ID Development and Safety Assessments



High Temperature Furnace Testing

SCADA

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NEXCERIS where energy meets environment

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BraytonEnergy

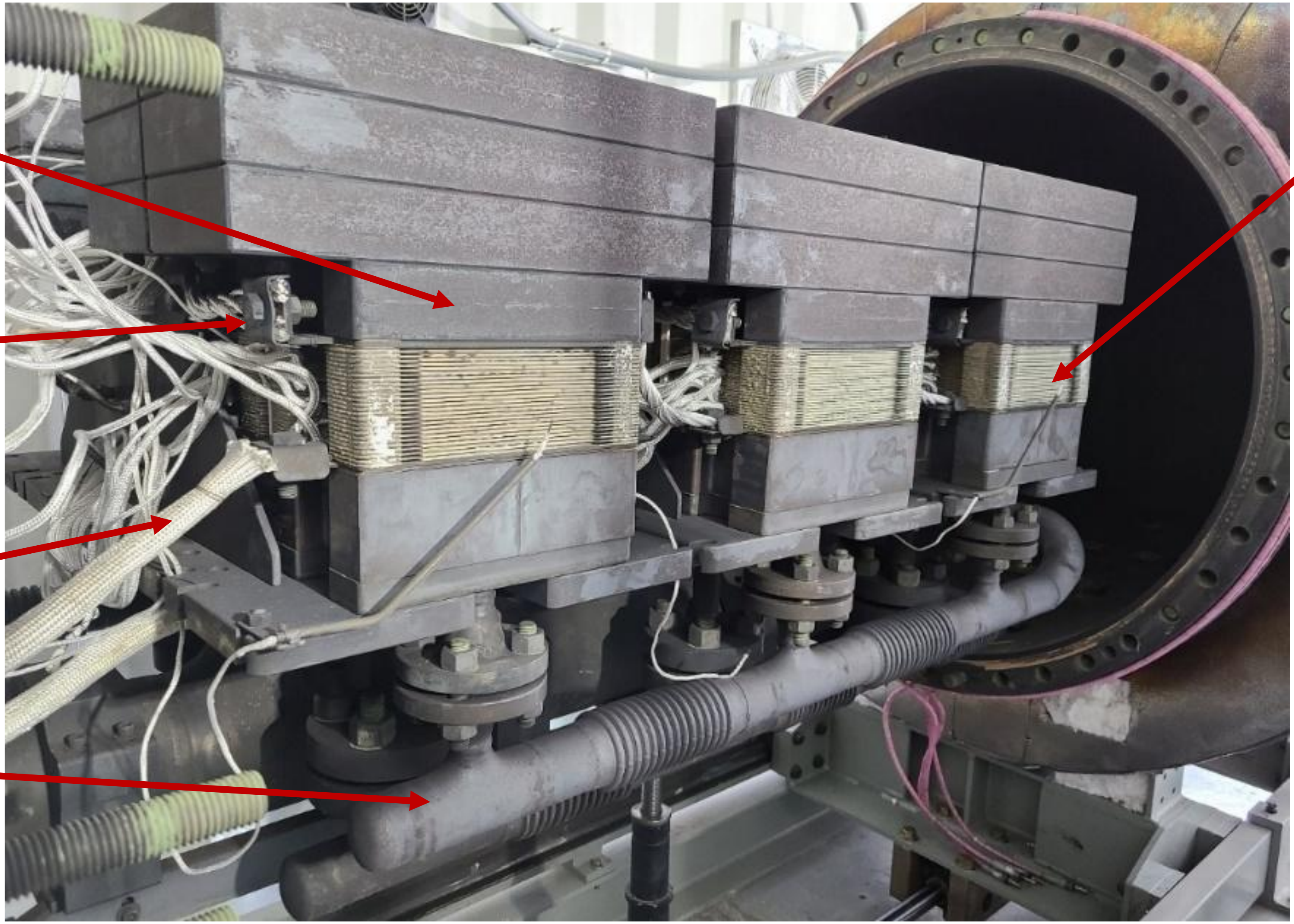
SOFC/GT – Demanding Materials Requirements

Corrosion resistant materials at 850°C+

High current power transmission with low resistance

Electrical insulation which remains flexible (doesn't glass over)

Metals which are not subject to hydrogen embrittlement



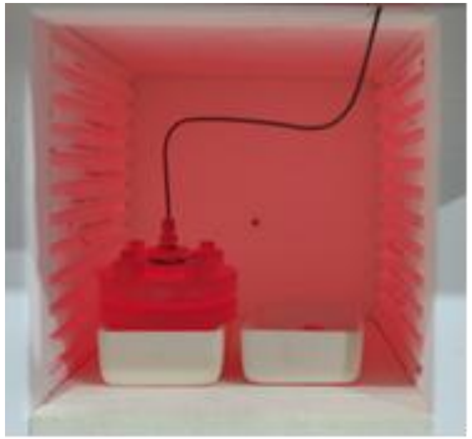
High-efficiency SOFC materials:

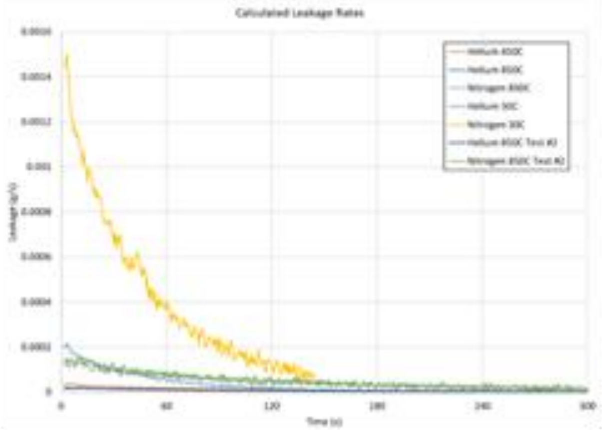
Electrolyte:
Yttria-stabilized zirconia

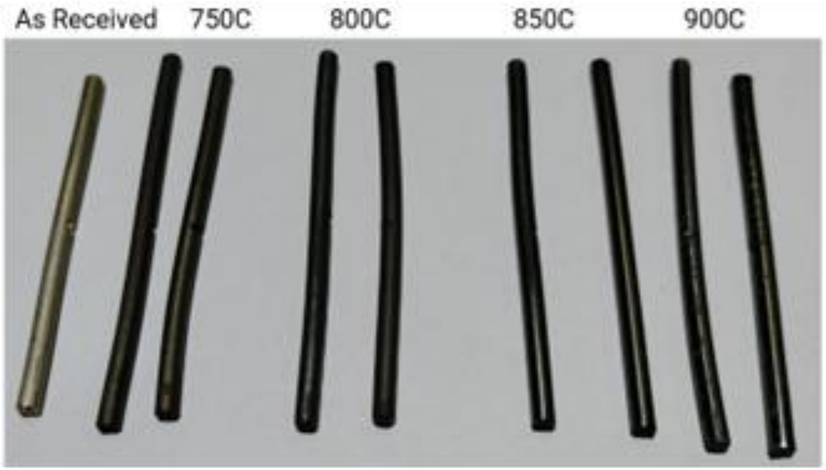
Anode:
Nickel-yttria stabilized zirconia

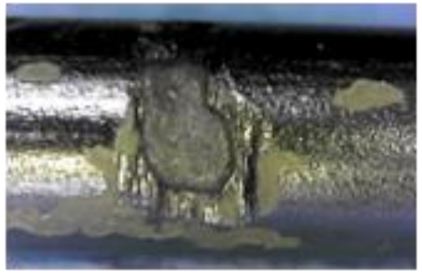
Cathode:
Lanthanum strontium manganite

SOFC/GT – High Temperature Material Corrosion

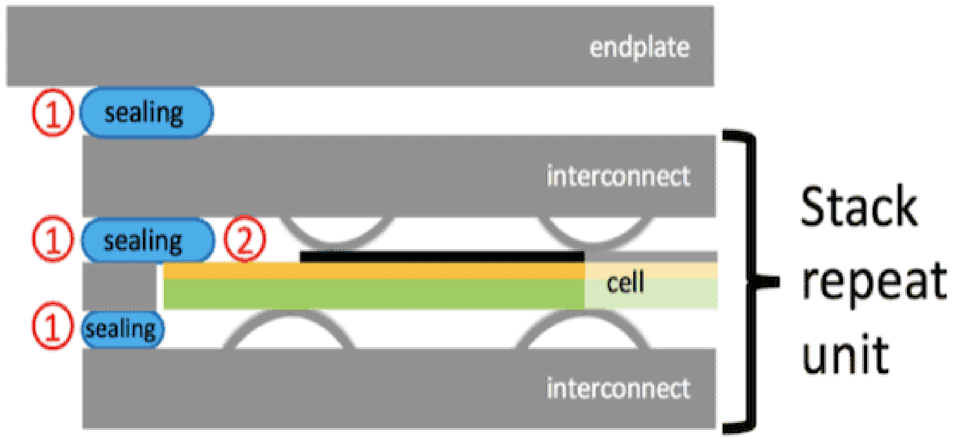


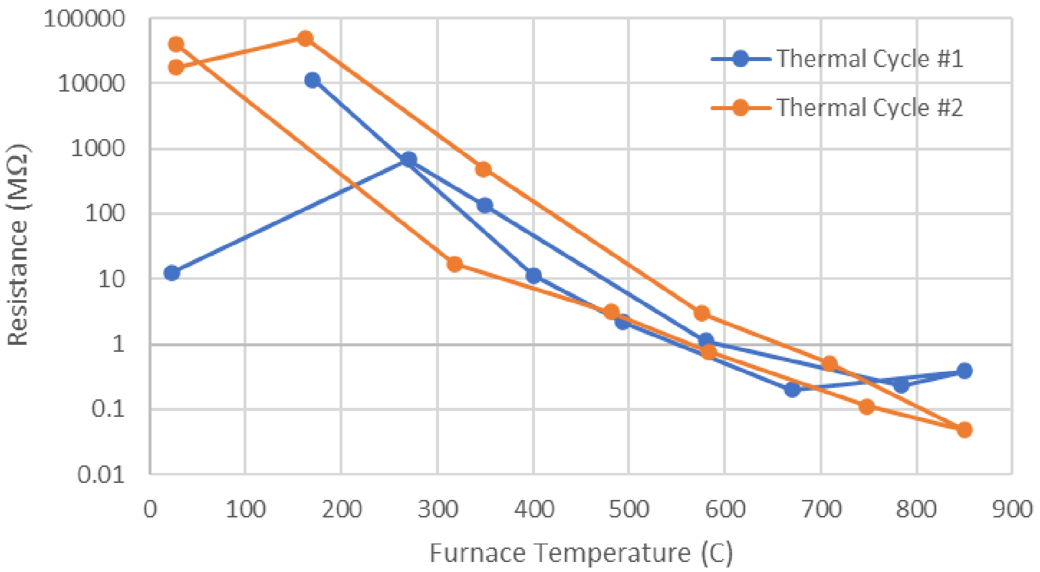


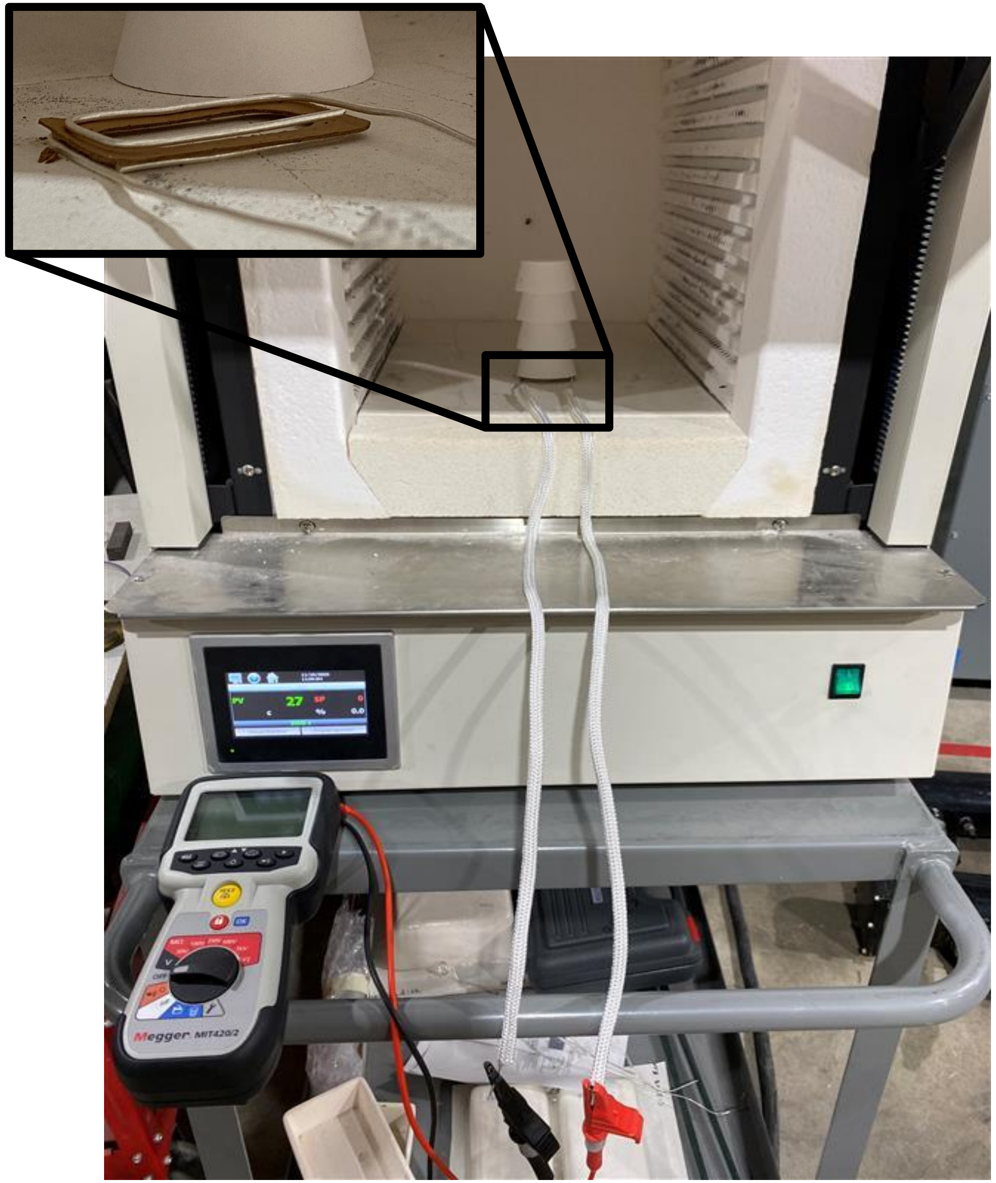




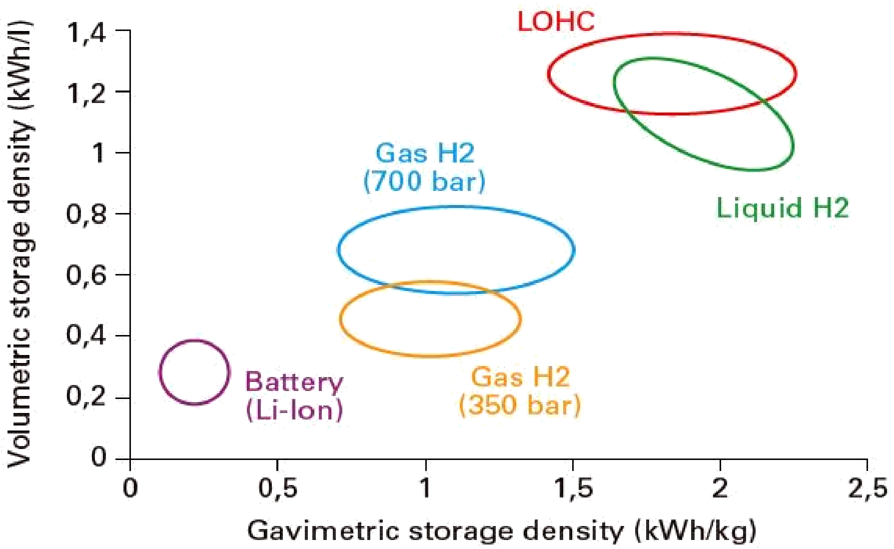
SOFC/GT – Electrical Conductivity of Insulation

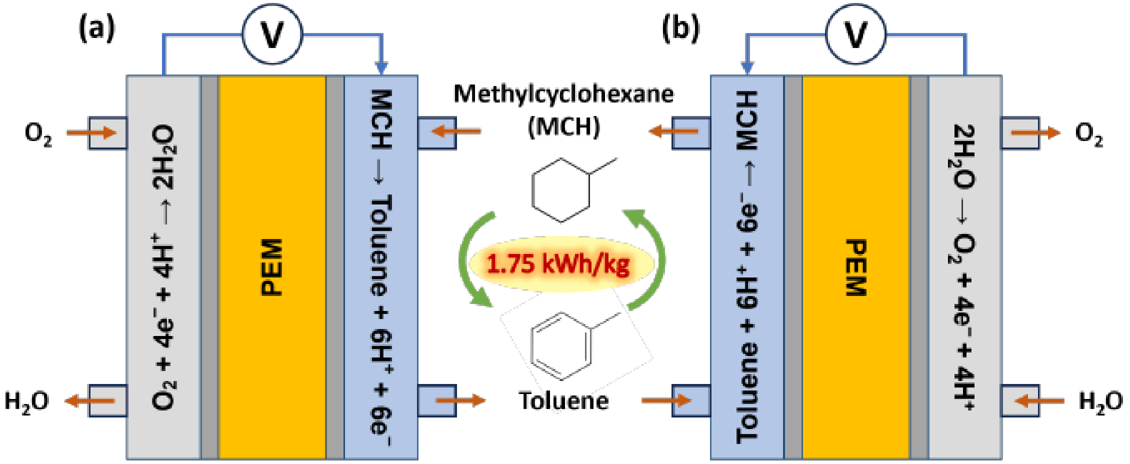


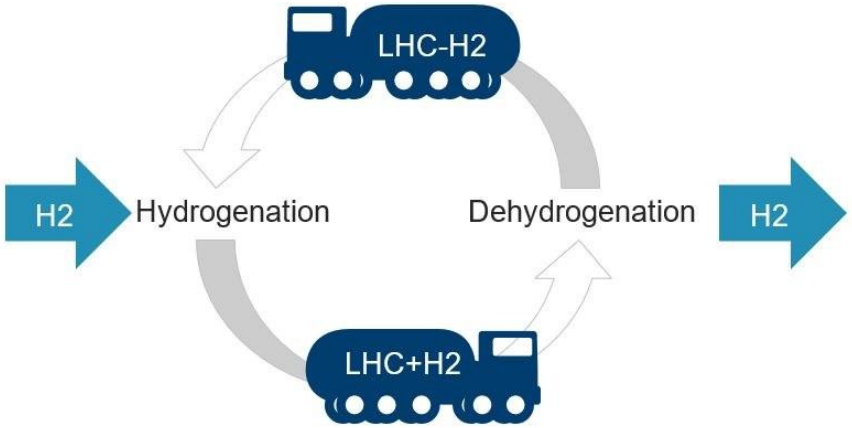




Liquid Organic Hydrogen Carrier: Methylcyclohexane/Toluene Fuel Cell/Electrolyzer







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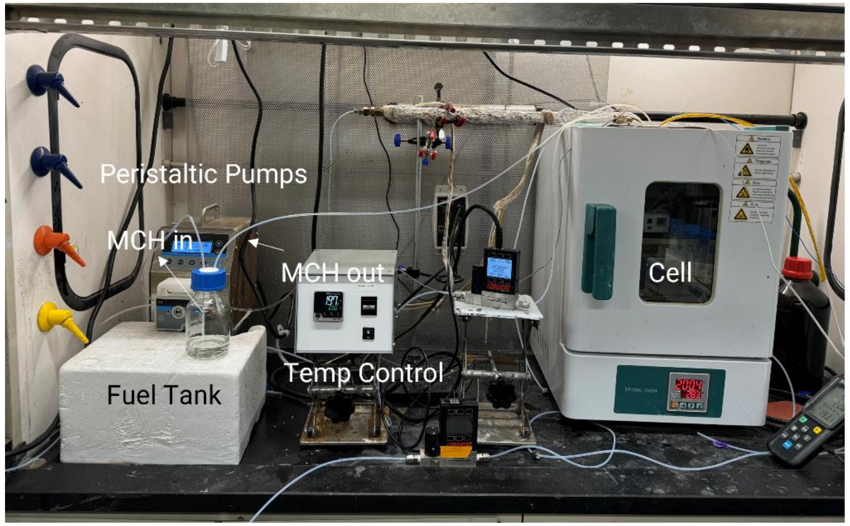
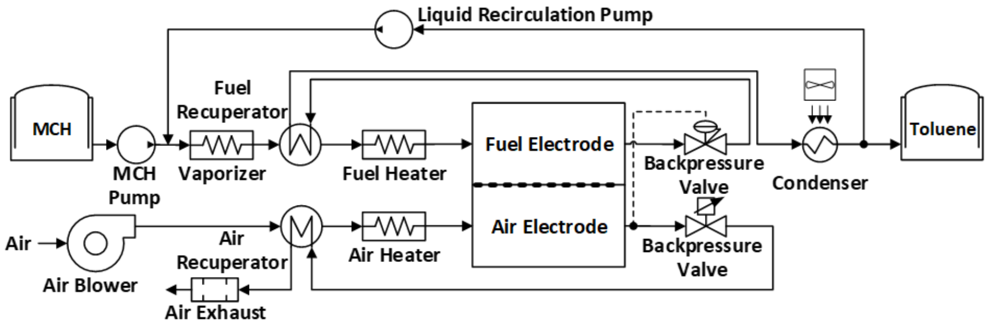
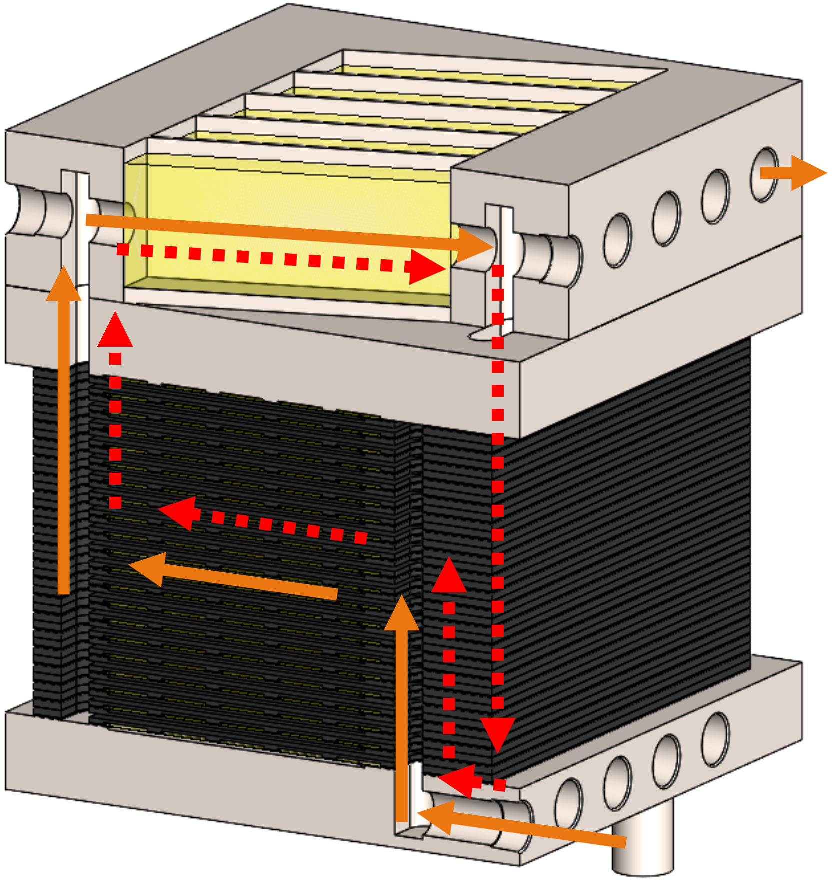
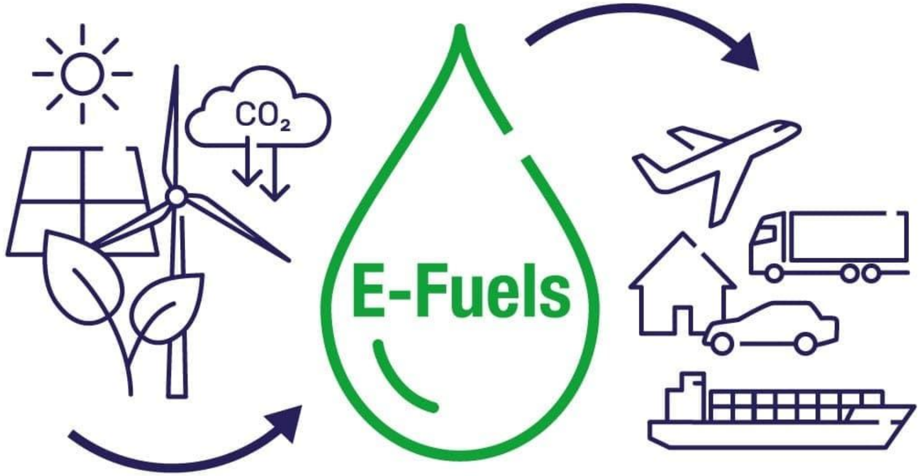
Liquid Organic Hydrogen Carrier: Methylcyclohexane/Toluene Fuel Cell/Electrolyzer



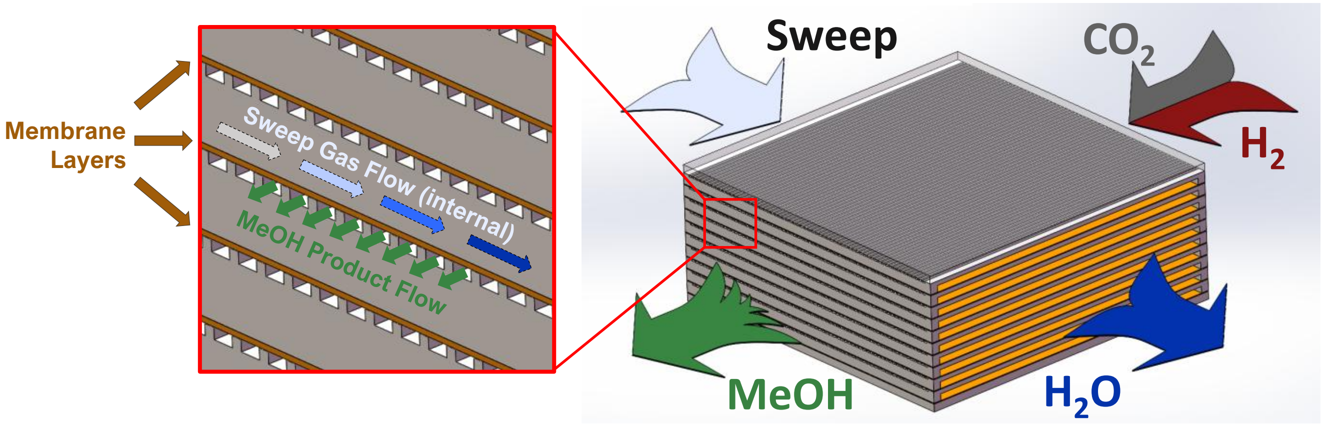




Direct CO_2/H_2 to Methanol Reactor Development



Microchannel Designs
Enhance Heat Transfer and Selectivity



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NEXCERIS — where energy meets environment

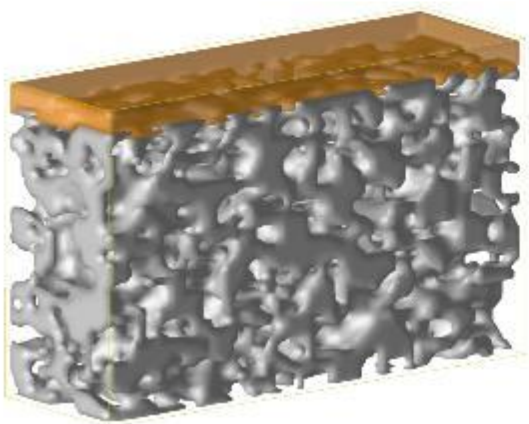
TONKOMO LLC

MoleculeWorks — Efficiency for a Sustainable World

WASHINGTON STATE UNIVERSITY

Czero — ENGINEERING TOMORROW

HeatPath manages heat and mass transfer in channels



Membranes remove water to break equilibrium

Select Czero Carbon Capture Projects

Point Source:

- Cryogenic carbon capture

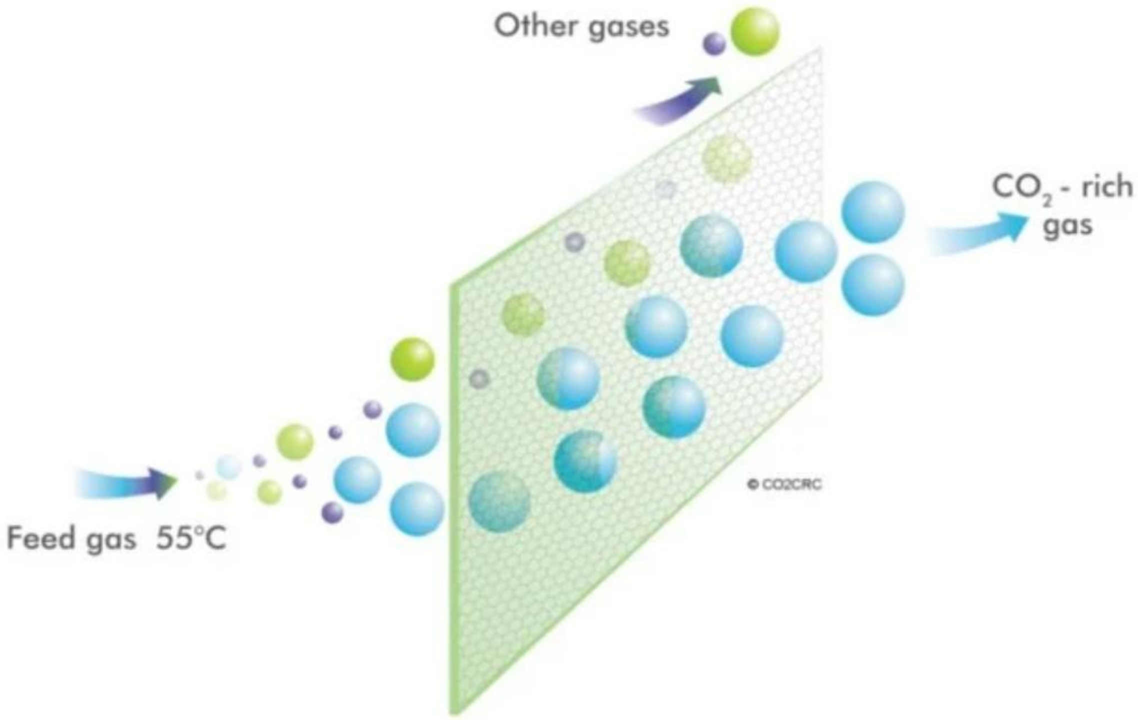
Direct Air Capture (DAC) Systems:

- Humidity swing adsorption CO_2 capture
- Photoacid based CO_2 capture
- Electrochemically produced acid-Base CO_2 capture
- Mineralization based CO_2 capture
- Stable biomass-based CO_2 capture and storage

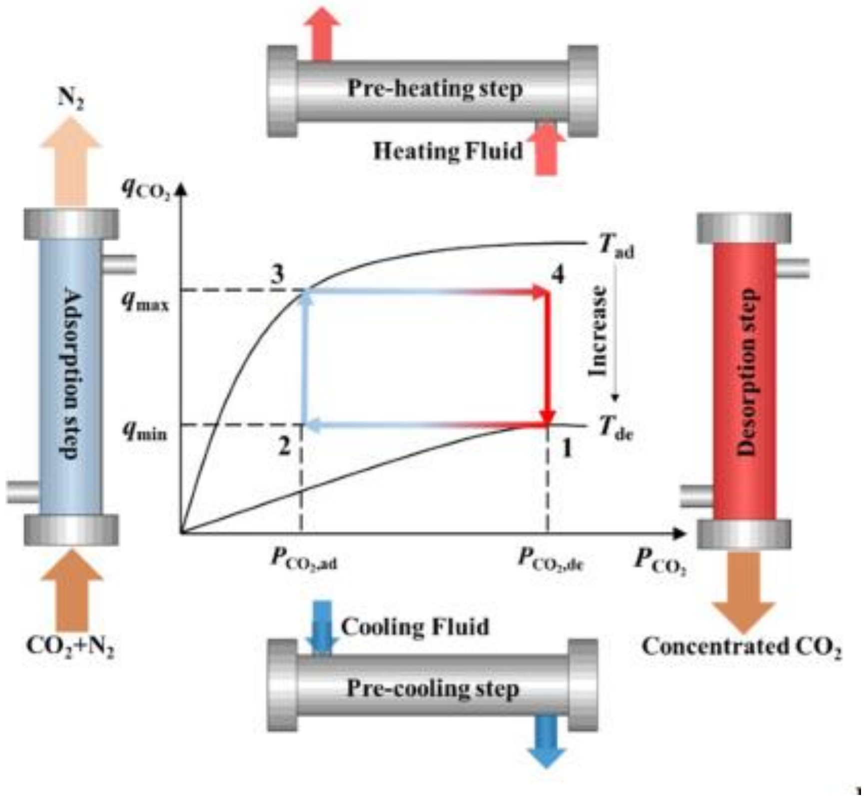
Carbon America's FrostCC™ deployed at NCCC

Carbon America

Carbon Capture and Sequestration: Membrane Based Systems

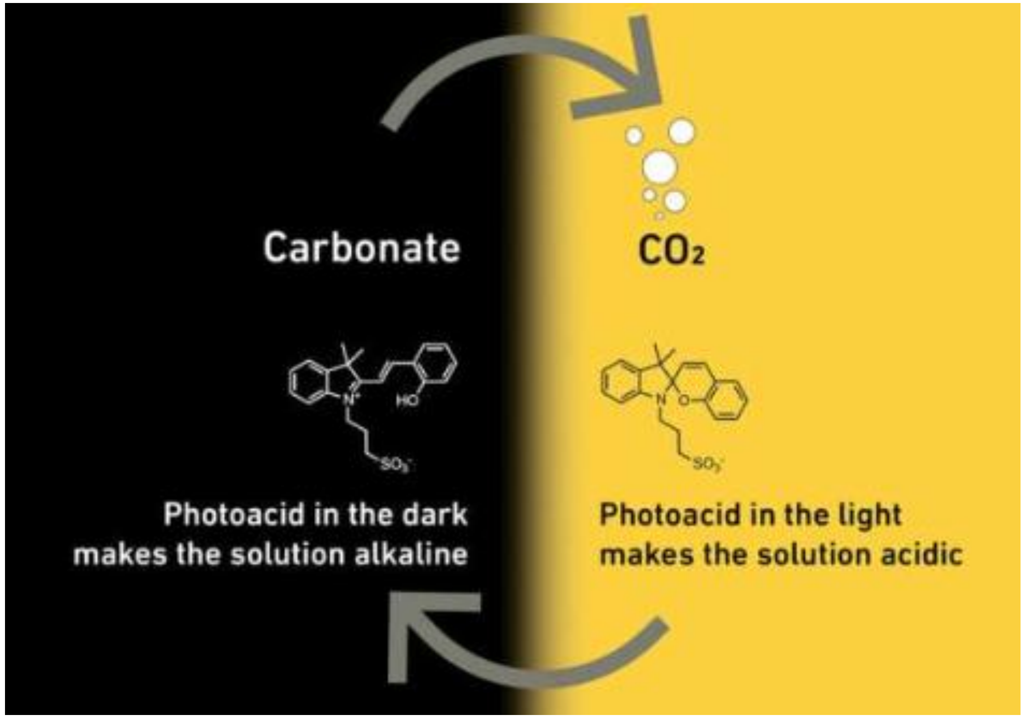


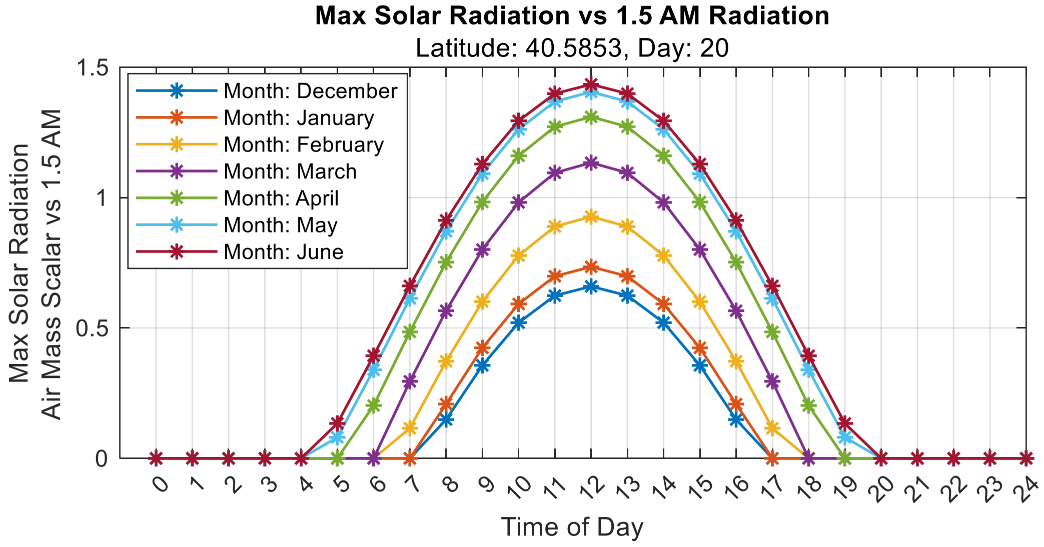
Membrane based separation

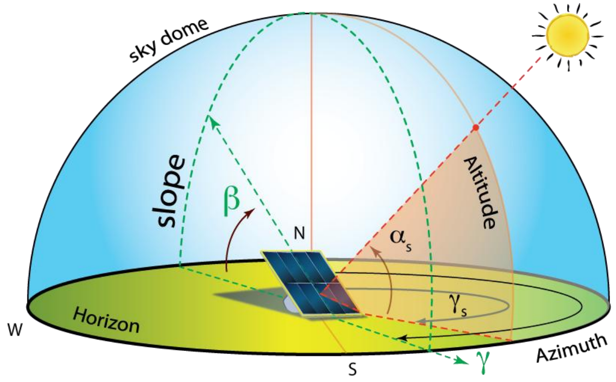


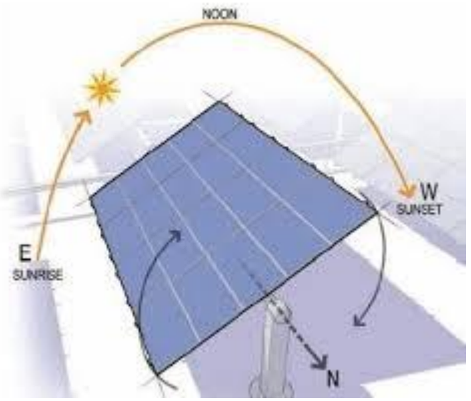
Pressure/temperature/humidity/etc. swing based absorption

Carbon Capture and Sequestration: Photoacid Chemical Processing









Key Takeaways

- For advanced materials to make a real-world impact they need to be viable in real-world applications

  Fundamental research is still highly valuable *“If I have seen further, it is by standing on the shoulders of Giants” – Isaac Newton*

- Many great materials may never reach the market due to a variety of challenges – If you know about potential challenges you may be able to address these in the material design

- The most impactful technologies will likely come out of close corporate between stakeholders (material science, engineering, manufactures, end users…)

- *“You don’t know what you don’t know”*

*If it **Works**, will it **Matter?***

The next big materials breakthrough almost certainty exists in a lab somewhere

The challenge is turning it into a technology that is practical, commercially viable, and impactful

*If it **Works,** will it **Matter?***

Thank you for your time!

Questions?

Please contact us:

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