SRNL-MS-2025-00097

Savannah River National Laboratory®

We put science to work.™

SRNL Innovations & Applied Technology to Address Environmental & Energy Efficiency Challenges

Joseph Manna, Director
Materials Technology & Energy Sciences Division
Environmental & Legacy Management Directorate

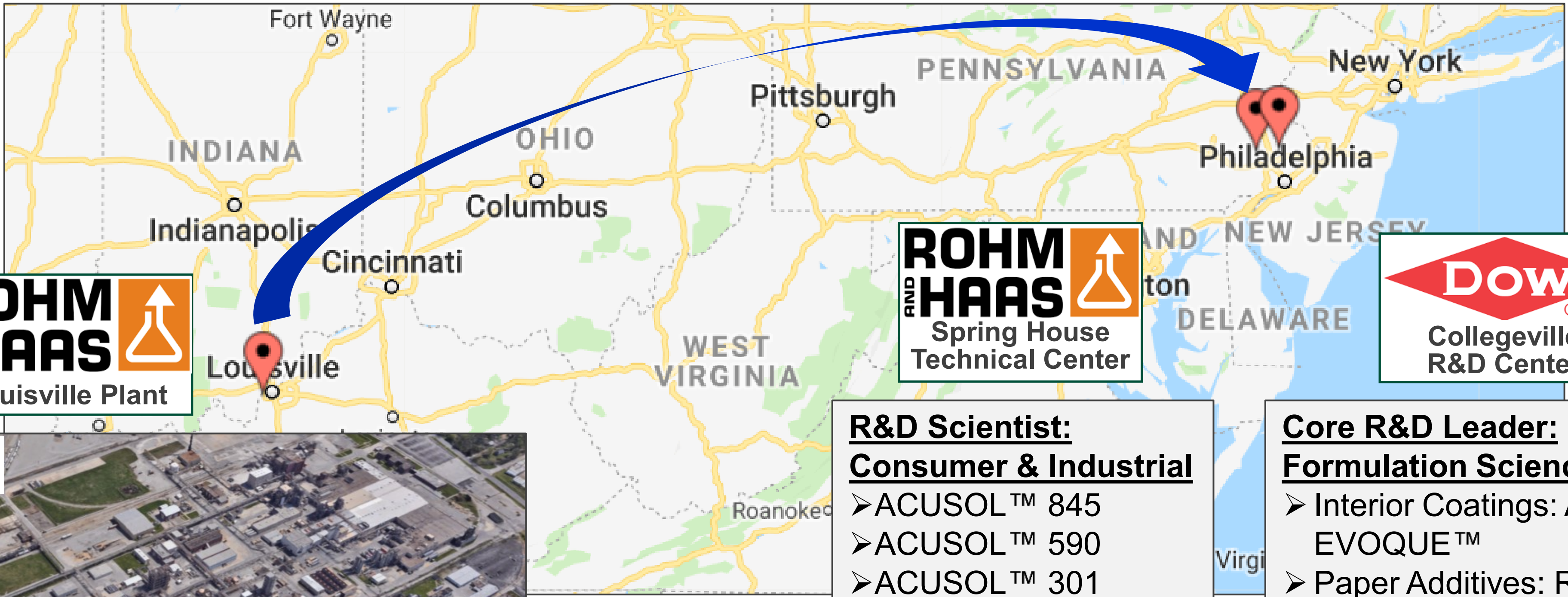
April 2025

Agenda

- Historical Industrial Perspective
- Savannah River Site
- SRNL Mission Overview
- Division Focused Applied Research & Technology
- Energy Program Highlights
- Hanford Environmental Cleanup Initiatives
- Advanced Manufacturing Collaborative
- Summary

My Industrial Experiences

Oligomeric & Polymeric Additives in Consumer & Industrial Applications



ROHM AND HAAS
Louisville Plant

ROHM AND HAAS
Spring House Technical Center

DOW
Collegeville R&D Center

Process Chemist: Plastic Additives

- PARALOID™ K-400 & K-435 Processing Aids
- PARALOID™ KM-399 Impact Modifier
- 6σ Waste Reduction Initiatives

R&D Scientist: Consumer & Industrial

- ACUSOL™ 845
- ACUSOL™ 590
- ACUSOL™ 301
- ACUSOL™ 498
- ROMAX™ 7005
- Polyacrylic Acid Supply Strategy

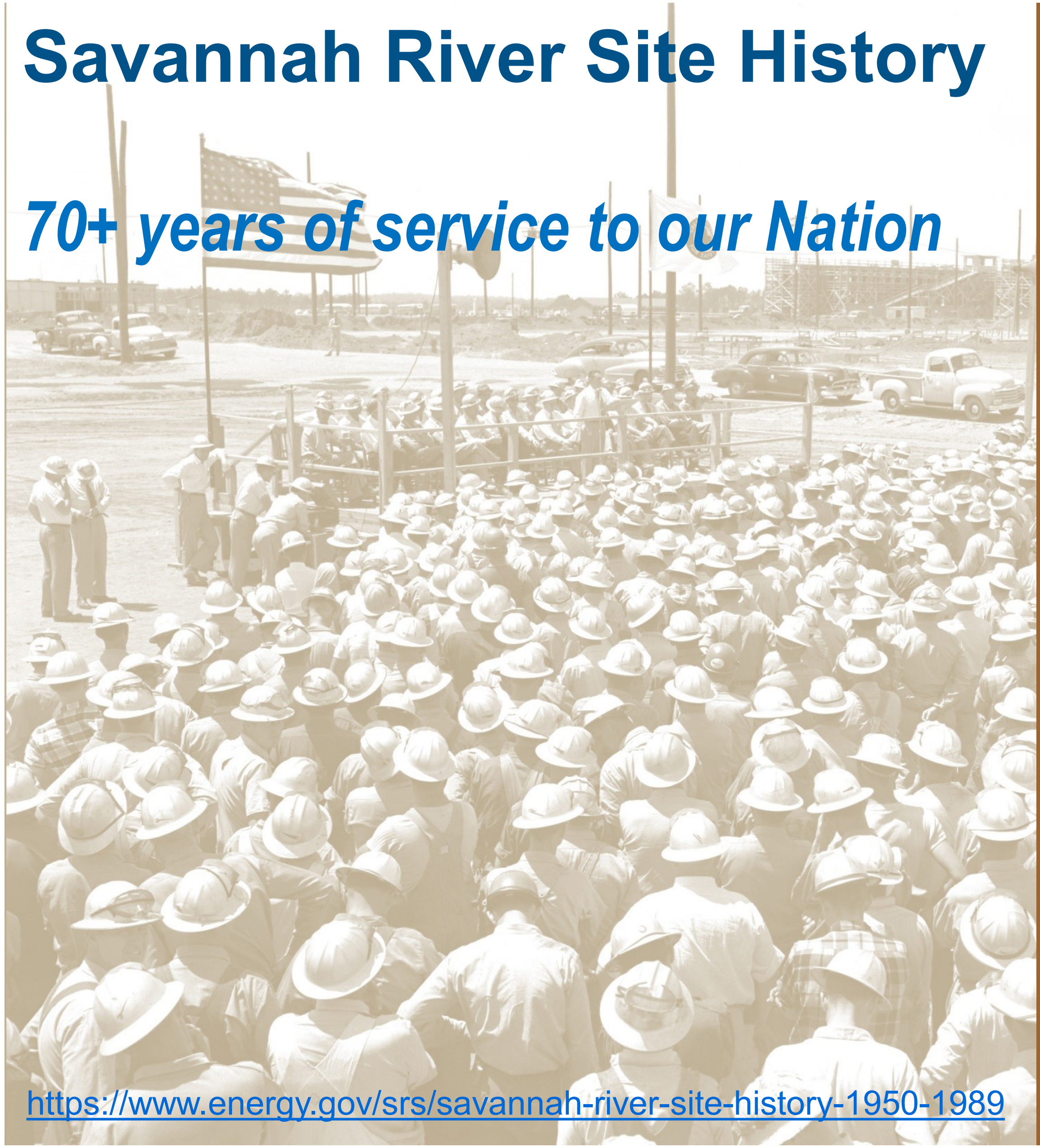
Core R&D Leader: Formulation Science

- Interior Coatings: ACRYSOL™ & EVOQUE™
- Paper Additives: ROPAQUE™ & RHOBARR™
- Wood Coatings: DOWSIL™
- Oilfield Additive: ROMAX™

PARALOID™, ACUSOL™, ROMAX™, ACRYSOL™, EVOQUE™, ROPAQUE™, ROBARR™, DOWSIL™ are registered trademarks of the Dow Chemical Co.

Savannah River Site History

70+ years of service to our Nation



https://www.energy.gov/srs/savannah-river-site-history-1950-1989

Sept. 23, 1949: President Truman announced Russia tested its first atomic weapon

June 12, 1950: Atomic Energy Commission (AEC) asks DuPont to build a plant to produce nuclear materials

Site selection considerations

- 100 potential sites
- Narrowed to three (Lake Superior; Red River in Texas & Savannah River near Augusta, GA)

Site requirements

- Large dependable source of water
- Topography for rapid construction
- Available labor pool
- Moderate climate
- Military defense (beyond range of Soviet bombers)

Nov. 28, 1950: AEC announces selection of location of Savannah River Plant between Aiken, SC, and Augusta, GA, on the Savannah River

www.srs.

The DOE's Newest National Laboratory

- Savannah River National Laboratory (SRNL) is one of 17 US Department of Energy (DOE) National Laboratories
- Multi-Program National Laboratory
  - Leading R&D institution for DOE Offices of Environmental Management and Legacy Management
  - Weapons and Nonproliferation programs for the National Nuclear Security Administration.
- Battelle Savannah River Alliance, LLC (BSRA), is a not-for-profit limited liability company, manages & operates SRNL for the DOE
  - BSRA Partners include
    - Battelle Memorial Institute
    - Clemson University,
    - University of South Carolina,
    - South Carolina State University,
    - University of Georgia,
    - Georgia Institute of Technology
    - Preferred subcontractors TechSource and Longenecker & Associates

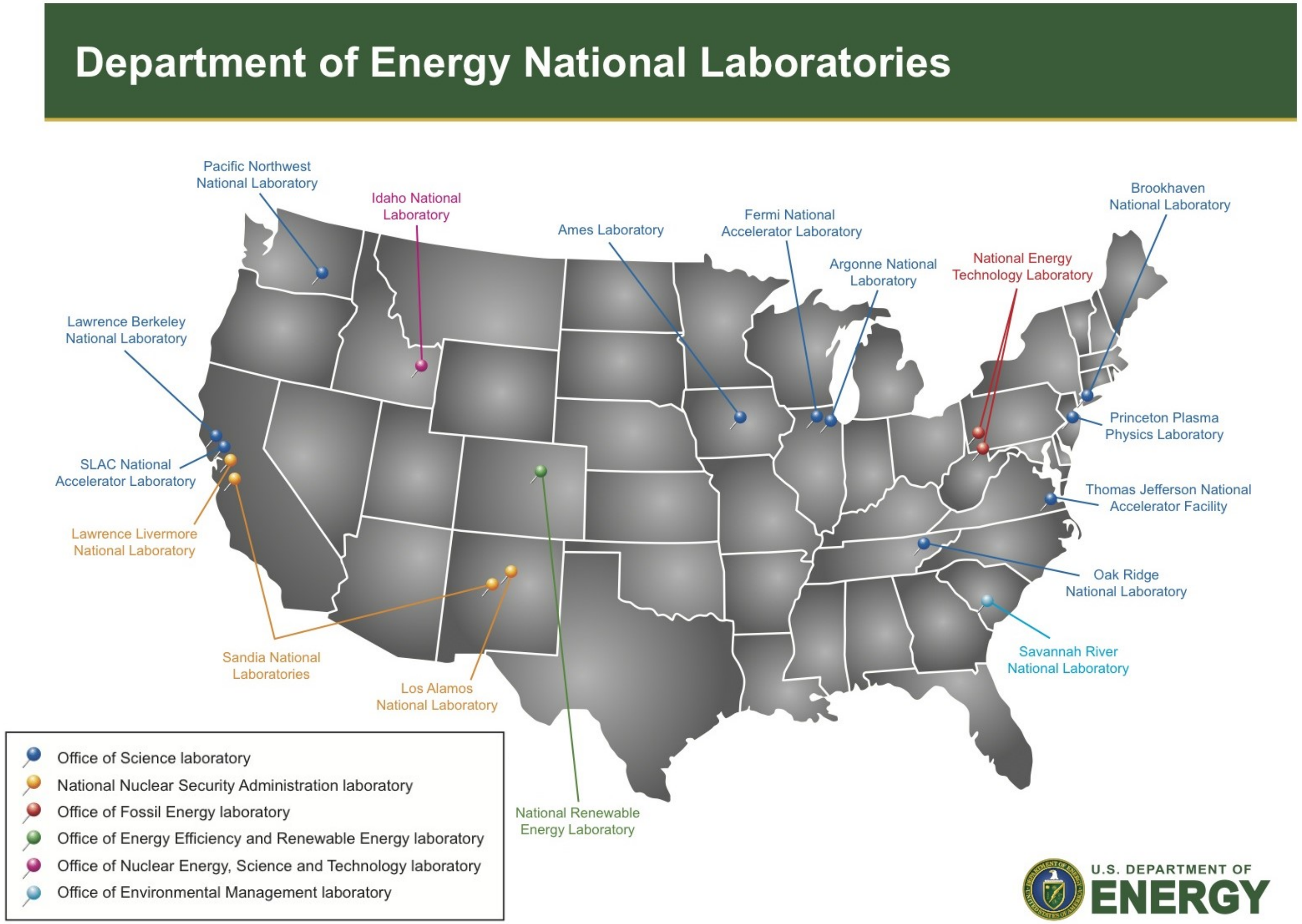
BSRA Battelle Savannah River Alliance, LLC

DOE Labs Perform a Critical Role for the Nation

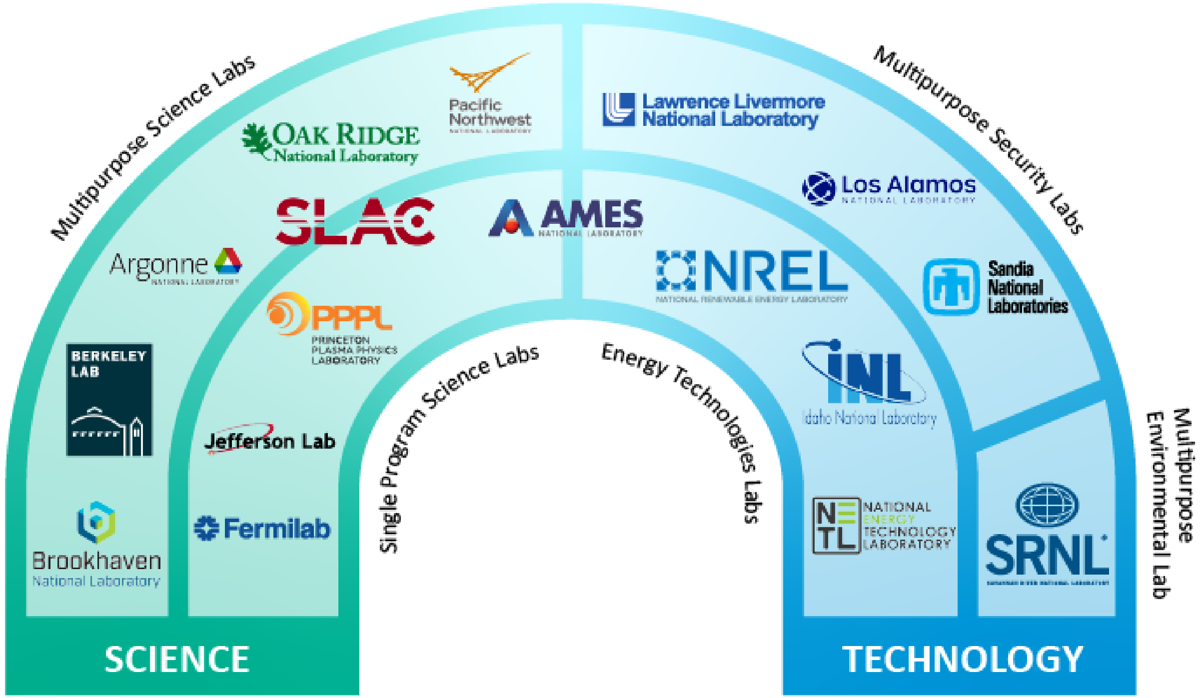
- Drive **scientific discovery and technological innovation** to support the **nation's defense and energy security**
- Stewards of **nation's unique facilities and capabilities**, **engaging partners** to advance US competitiveness.
- Test ideas from **bench to test-bed scale**, then transfer to industry & commercial partners
- Explore innovative approaches to collaboration to **accelerate technology deployment**
- Focus on **enduring national needs** in key technology & scientific spaces (long-term strategic perspective)

SRNL Shielded Cell Facility

SRNL is one of 17 DOE National Laboratories



SRNL is DOE's only Environmental Management & Legacy Management Office Lab



The State of the DOE National Laboratories, 2020
https://www.energy.gov/articles/state-doe-national-laboratories-2020-edition

Graphic: energy.gov

SRNL at-a-Glance

Assets

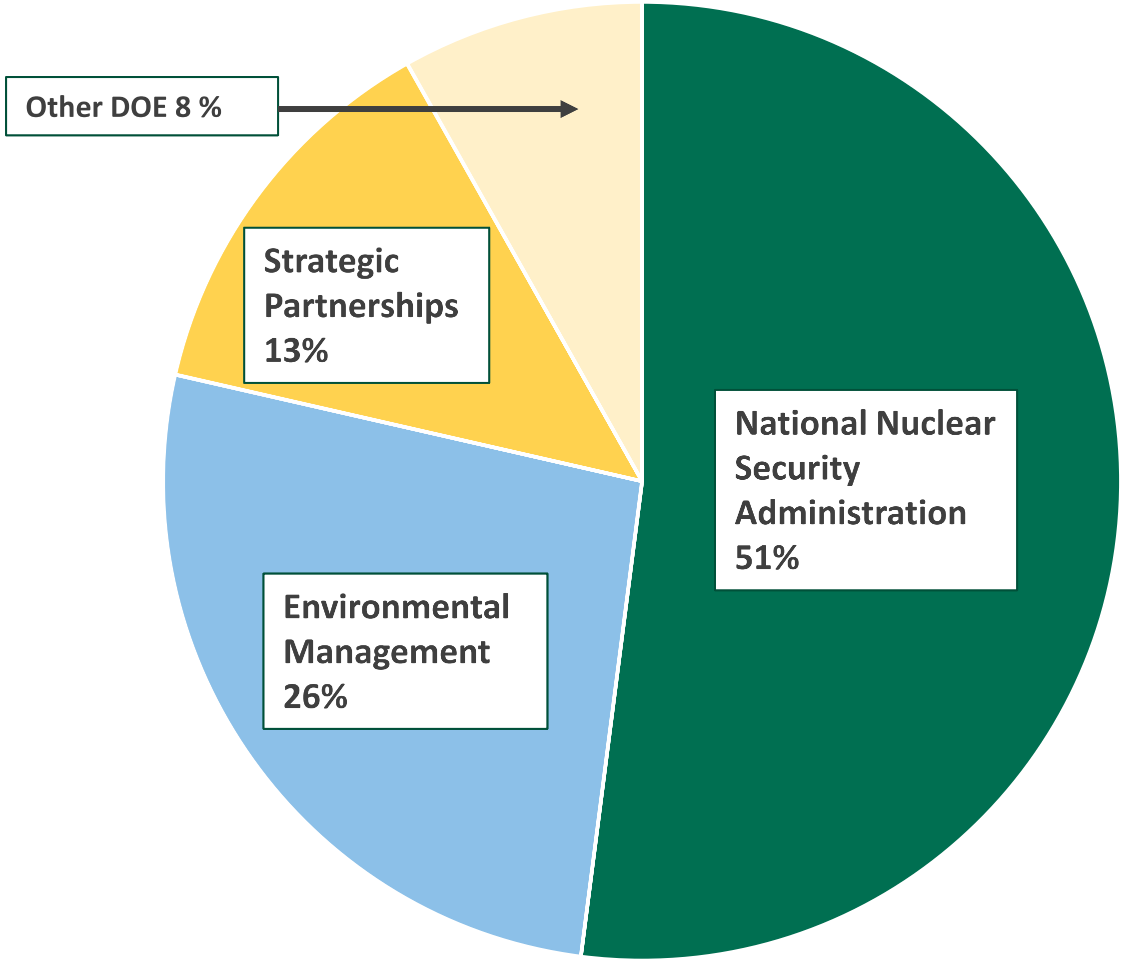
- 39-acre main campus in Aiken, South Carolina, is valued at $2 billion
- 15 nuclear facilities with more than 200,000 square feet of radiologically controlled laboratories and process spaces

Human Capital

~1,400 people contribute to the SRNL mission

- Employees
- Postdoctoral Researchers
- Joint appointments
- Contract Staff
- Undergraduate & Graduate Interns

Program Execution (~$400M)



Our Vision Focuses on Three Mission Outcomes

Environmental & Legacy Management

Provide risk-informed approaches that achieve sustainable regulatory end-states.

National Security

Enable NNSA success by supporting a robust weapons stockpile while reducing threats through advances in proliferation detection technologies.

Science & Energy Security

Develop environmentally responsible and secure energy strategies through advanced engineering of materials and chemistry.

Enabled by a Workforce Development Initiative

Deliver the intellectual resources needed to execute the vision for the nation.

SRNL Mission and Vision Statement

SRNL Vision

To be a national leader for translating scientific discoveries into innovative solutions that strengthen national security, accelerate environmental stewardship, and enhance energy resilience

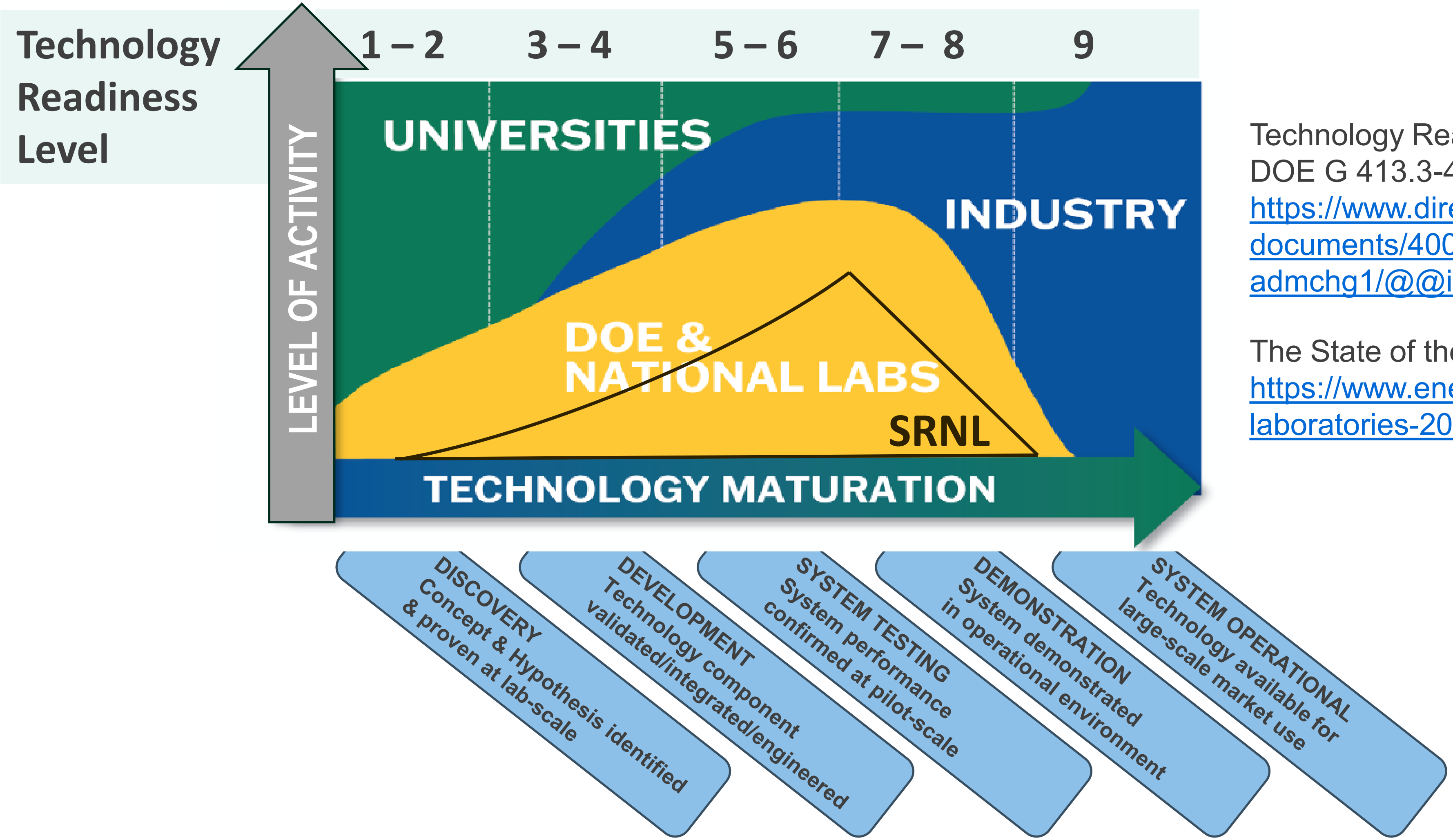
SRNL Mission

SRNL puts science to work to protect our environment, serve our national defense, secure our clean energy future and reduce emerging nuclear threats.

SRNL Core Values

Integrity, Innovation, Teamwork and Service

DOE National Lab Relationship to Universities & Industrial Partners



Technology Readiness Assessment Guide
DOE G 413.3-4A, Chg 1, 10/22/2015
https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04a-admchg1/@@images/file

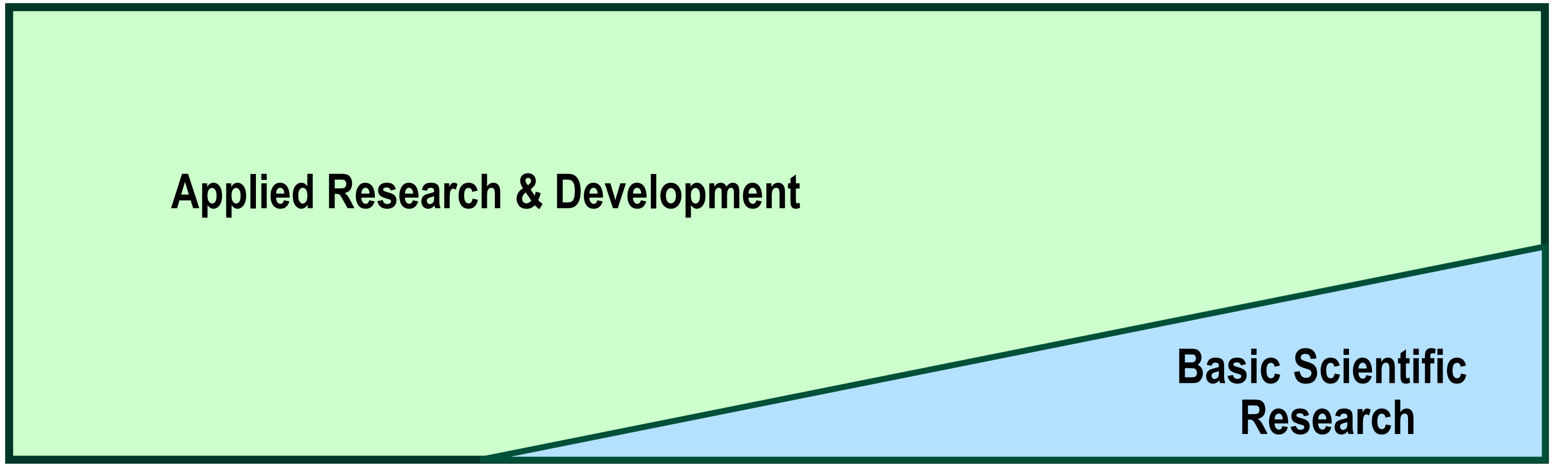
The State of the DOE National Laboratories, 2020
https://www.energy.gov/articles/state-doe-national-laboratories-2020-edition

Materials Technology & Energy Sciences Division

Materials Technology & Energy Sciences

- Materials, Non-Destructive & Systems Evaluation
- Materials Science & Nuclear Materials Disposition
- Glass, Cement, & Ceramic Science
- Advanced Materials & Process Technology

Relative Level in Each Group



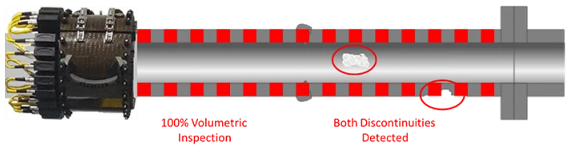
Non-Nuclear Mission: Providing a Transformational Bridge through the implementation of applied technology to support US Energy and Industrial Growth

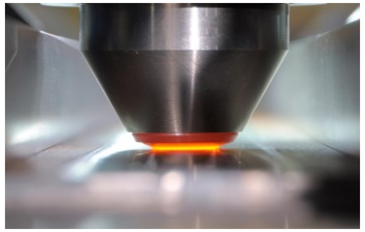
Integration into the Advanced Manufacturing Collaborative with Industry Partners

Nuclear Mission Focus - Materials Technology & Energy Sciences Division

➢ **Legacy Thrusts: Focus on Traditional Environmental Management Sites Mission Needs**

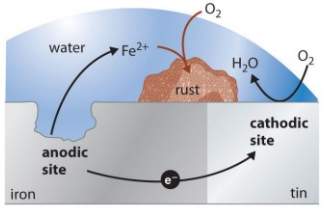
Non-Destructive Evaluation & Welding Technology





Focus: Provide NDE & welding technology support to DOE site facilities and missions, including development and implementation of advanced techniques.

Corrosion Science & Material Integrity



Focus: Testing, evaluation & investigation of materials performance in critical, aggressive & multivariable service environments to support Packaging & Material Integrity needs, extending into the DOT and Oil & Gas industry.

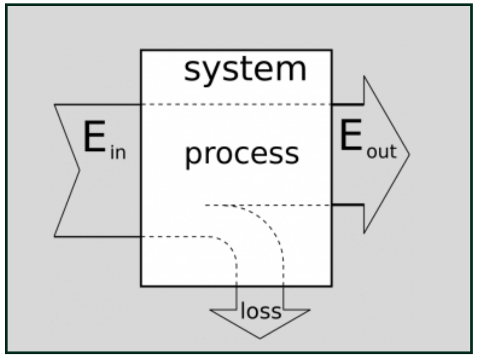
Wasteform Technology Development

Focus: Evaluate processing and material performance requirements of waste streams and identify current, or develop new, treatment and wasteform options to meet disposal requirements.

Non-Nuclear Mission Focus - Materials Technology & Energy Sciences Division

- Focus on the nation's energy needs, critical resources, environmental management challenges & quantum materials

Manufacturing Industrial Efficiency

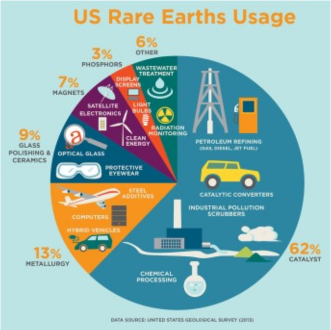


Focus: Develop manufacturing technology, including Nanotechnology, alternative processing approaches & feedstocks to transform industrial processing

Waste Processing & Upcycling of Materials

Focus: Nanotechnology & processing methodologies to transform polymer, glass, & other waste streams into materials with performance benefits and economic value

REE & Critical Materials Recovery-Processing



Focus: Identify cost effective separation & processing technologies for Critical Materials, Critical Minerals, & REE recovery, production and reuse

Credit: US Geological Survey

Crystalline Materials with Quantum Properties

Topological insulator ingot (Sb_2Te_2Se) grown

Focus: Synthesis of novel inorganic materials for high performance computing, magnets, sensors, and energy generation to advance national security, energy, and medical applications

Thermocatalytic Ethylene Production Using Targeted RF Induction Heating

SRNL Leads: Dr. Hector Colon-Mercado and Dr. Matthew Craps

Goal: To convert ethane to ethylene using Radio-Frequency (RF) induction heating by employing an oxidative dehydrogenation process of ethane with CO_2

SRNL Focus: Susceptor-catalyst development, bench-scale and pre-pilot scale reactor design and testing

Collaborators:

National Renewable Energy Laboratory: Atomistic modeling of RF reactor coupled catalysts

Electric Power Research Institute & RAPID Institute: TEA/LCA

University of South Carolina: Catalyst optimization & modeling

Induction Food Systems (IFS): Reactor design & scale-up

Bechtel: Industrial engineering guidance/Process modeling

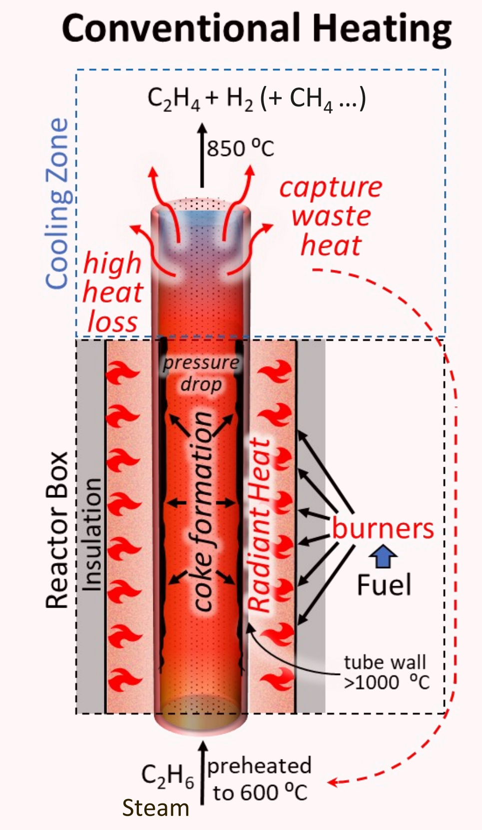
Contact:
Hector.Colon-Mercado@srnl.doe.gov
Matthew.Craps@srnl.doe.gov

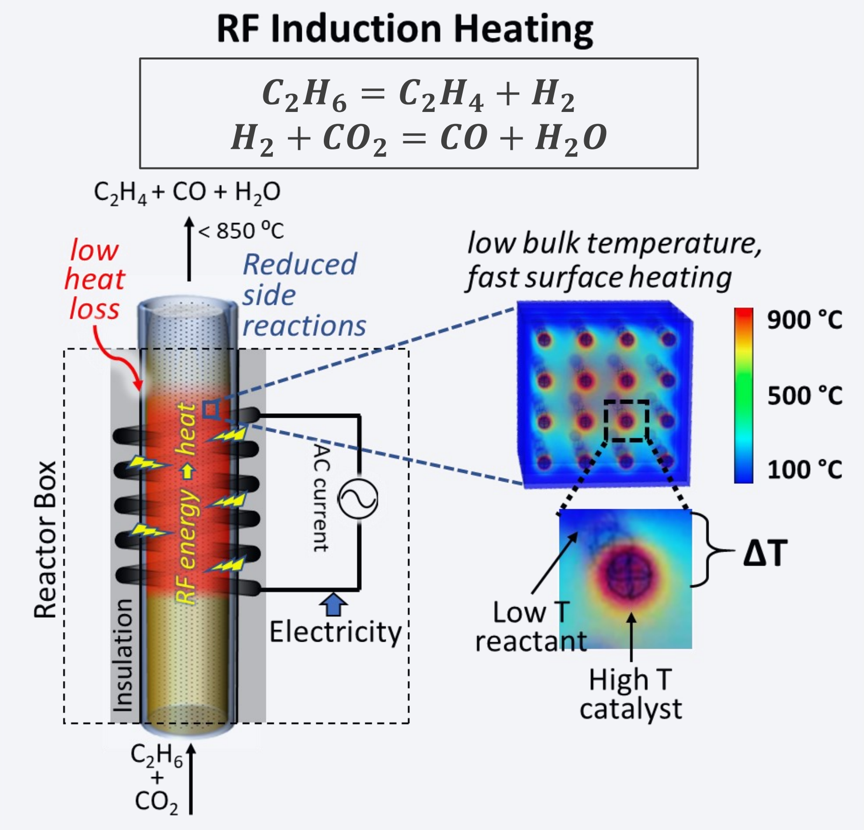
Funding source:
DOE EERE-AMO

Thermocatalytic Ethylene Production Using Targeted RF Induction Heating

Conventional vs. Radio Frequency Heating

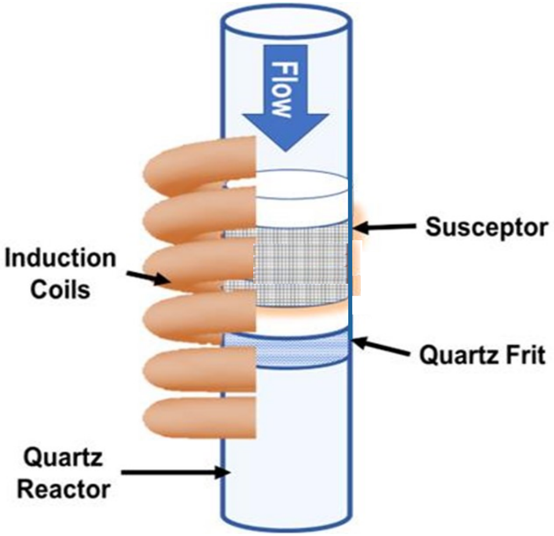
- **Many alternatives to Steam cracking proposed**
  - Most require combustion-based heating
- **RF induction heating advantages**
  - Rapid modulation of Reaction temperature (allows for process that integrates with electric power source)
  - Reduce radiant heat losses ⇒ Reduce energy intensity
  - Allows direct delivery of heat to the catalyst, ideal for endothermic reactions
- **CO_2 used as a soft oxidizer (**Oxidative Dehydrogenation)
  - Avoids safety issues of traditional Oxidative Dehydrogenation of Ethane
  - Suppresses the catalyst deactivation due to coke formation
  - Employs CO_2 as feedstock



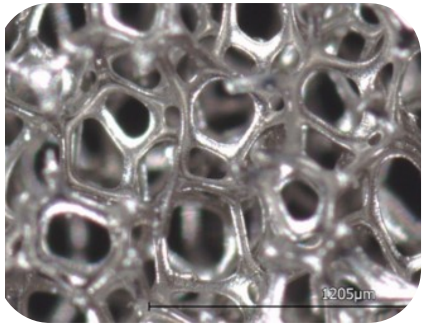


➢ Uses natural gas to Heat	vs	Alternative electricity options
➢ CO_2 created by combustion	vs	Consumes CO_2
➢ Long reactor towers	vs	Shorter reaction bed
➢ Continuous operation	vs	Quickly shutdown & startup

Results: Ethylene Production Using Targeted RF Induction Heating

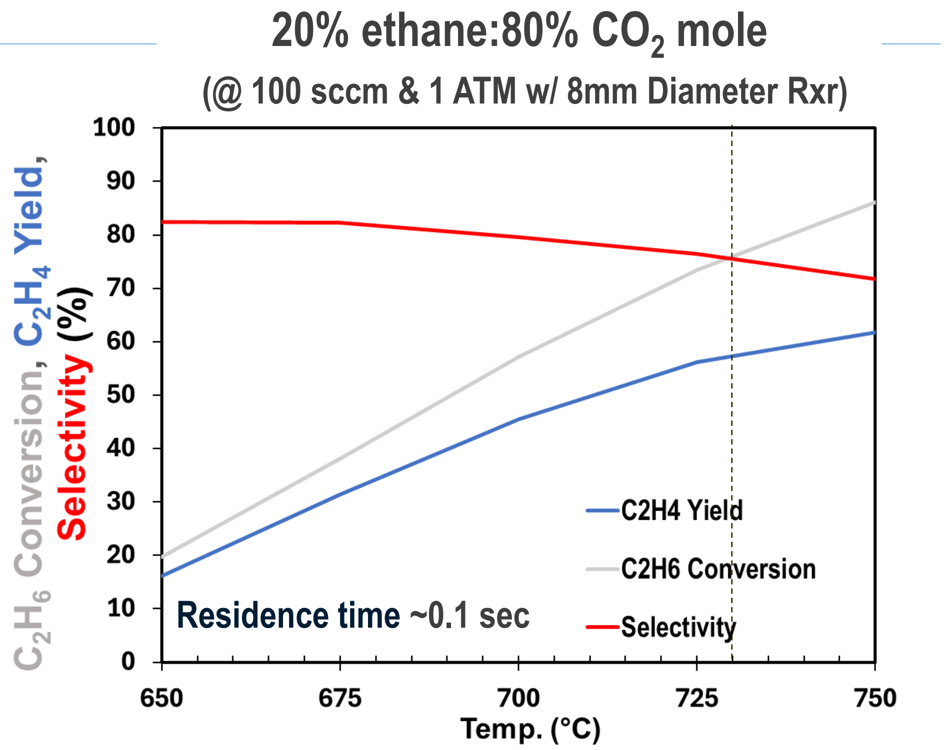


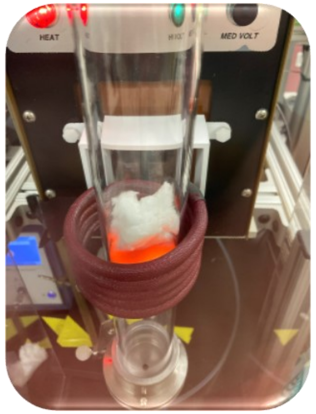
- Better reaction control
- Higher absorption efficiency
- Oxidation control with appropriate coatings
- Reduced Coke buildup at lower Temp



Ni foam (300-500 μm pore size)

Oxidation Resistant Coating





- 2 in Diameter Reactor run @ 1000 sccm
- Photograph of pre-pilot scale induction reactor operating at ~500 watts & 250 KHz

- Ethane conversion & Ethylene yield increased as the Temperature increased. ∗ Ethylene selectivity decreased.
- Observed 75% Ethane selectivity, 76% Ethane conversion, and 57% Ethylene yield (730 °C)
- Literature: Steam Cracking: ~83-90% selectivity, ~63-68% ethane conversion, and ~54-61% ethylene yield (850-950 °C)

Commercialization Challenges

SRNL role:

- Engage with large chemical manufacturers & engineering firms to implement the technology, from lab scale to pilot scale

Commercialization Barriers:

- CapEx questions on scale up: Industrial Ethane Crackers cost ~$1.6+ Billion
- Modular reactors provide more flexibility on location and operational start up time, but need to validate at Pilot Scale to assess Selectivity, Conversion, and Yield. (Mitigate engineering scaling risks)
- TEA/LCA is being assessed by RAPID/EPRI
- Impact of downstream byproducts and required gas separations needs to by assessed, and ROI Scenario Calculations

TRL: Starting 2-3, Final 5-6

Funding Selection Announcements

https://www.srnl.gov/news-releases/srnl-awarded-two-doe-contracts-providinginnovations-inchemical-processing-and-dryingrd/

https://www.energy.gov/eere/ammto/advanced-manufacturing-office-fy20-multitopic-foa-selections-table

New Program:
Electromagnetic-Assisted Electrochemical Conversion of CO_2 to High Value Chemicals

SRNL Team: Matthew Craps (Lead), Prabhu Ganesan, and Tyler Guin

Goal: Design & construct an Electromagnetic-assisted alkaline electrochemical reactor for the conversion of CO_2 into useful products (focus on Ethylene and Acrylic Acid)

SRNL: Reactor design, testing, catalyst, and electrode development

Collaborators:

Mainland Solutions: Reactor scale-up

University of South Carolina: Multiscale modeling

Rapid Advancement in Process Intensification Deployment (RAPID) Institute: TEA/LCA

Siemens: TCA/LCA

Dow Chemical: Project consulting

Contact: Matthew.Craps@srnl.doe.gov

SRNL SAVANNAH RIVER NATIONAL LABORATORY

UNIVERSITY OF South Carolina

Mainland Solutions LLC

RAPID

SIEMENS

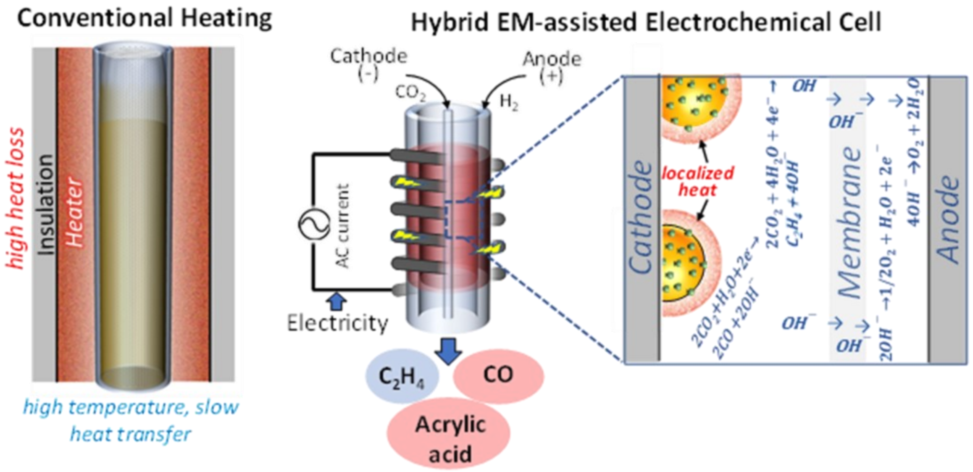
DOW

Funding source:
DOE EERE: IEDO

Electromagnetic-Assisted Electrochemical Conversion of CO_2 to High Value Chemicals

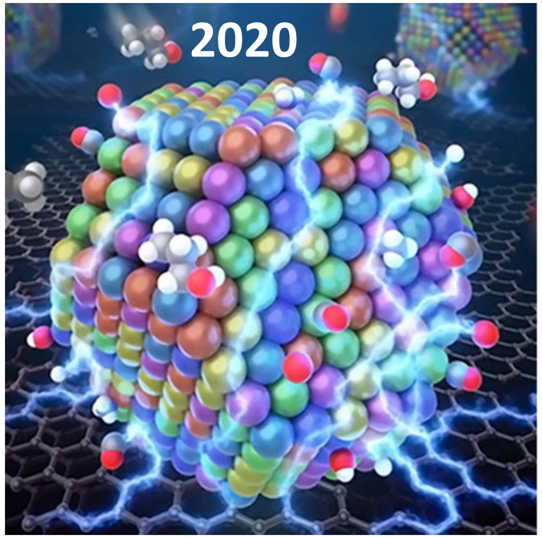
Quantitative Goal: Design & construct an EM-assisted alkaline electrochemical reactor to
- ❖ Demonstrate >80% conversion of CO_2 to ethylene, with faradaic efficiency ≥80%,
- ❖ Demonstrate conversion of CO_2 ≥10% to acrylic acid.

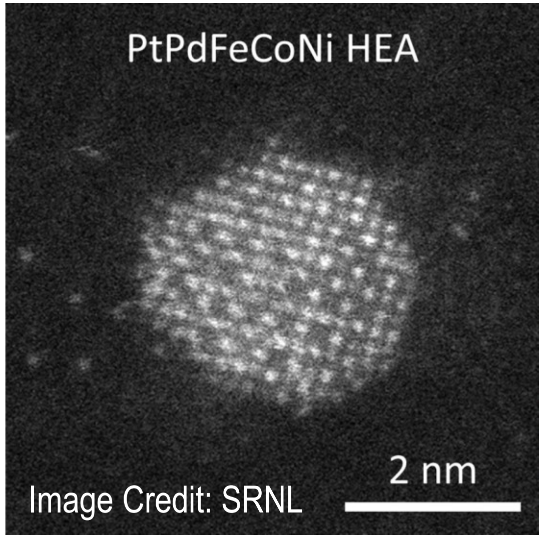
Strategic Goal: Demonstrate a continuous hybrid reactor with input CO_2 supply to convert over 1 kg product per day.



Induction field applies localized heating, an alternating magnetic field and added current to catalyst & cathode.

High Entropy Alloy (HEA) Catalysts consisting of 5 or more elements are utilized to perform complex cascading reactions

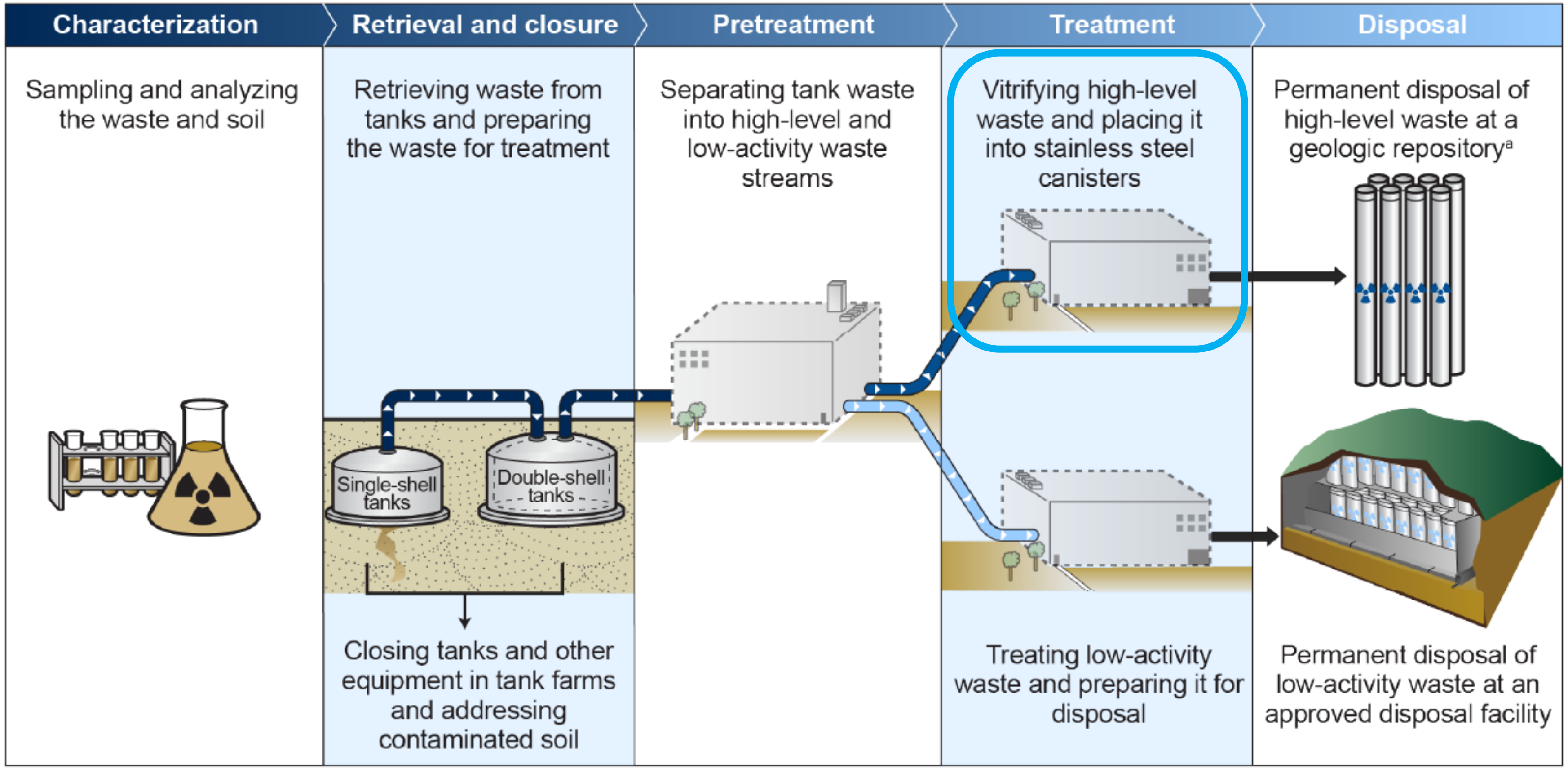




High Resolution Transmission Electron Microscope
- ➢ Micrograph showing individual atoms comprising the HEA

Image modified from Kyoto University: https://scitechdaily.com/entering-the-nanoscale-platinum-age-first-high-entropy-alloy-made-of-all-six-platinum-group-metals/

DOE Hanford Site Tank Waste Mission Challenges



Source: GAO analysis of Department of Energy documents. | GAO-22-104365

	DOE's current baseline approach	Alternative approach
Waste form	Glass	Grout
Disposal site	Hanford Integrated Disposal Facility, Washington	Several options, including two federal facilities in Washington or Nevada and two commercial facilities in Texas and Utah
Total cost	$21 - $37 billion	$11 - $13 billion

Sources: GAO analysis of Department of Energy (DOE) and disposal site documents, photos: GAO-22-104365

<u>54 Million Gal of Radioactive Tank Waste</u>

- **Low-Activity Waste (LAW): ~51 Million Gal**
- **High-Level Waste (HLW): ~3 Million Gal**

<u>Planned Immobilized Wasteform</u>

- **Vitrification of LAW: 51 M Gal**
  ⇒ Up to ~20 M Gal grouted
- **Vitrification of HLW: ~3 M Gal**
- **Secondary Waste Grouting**

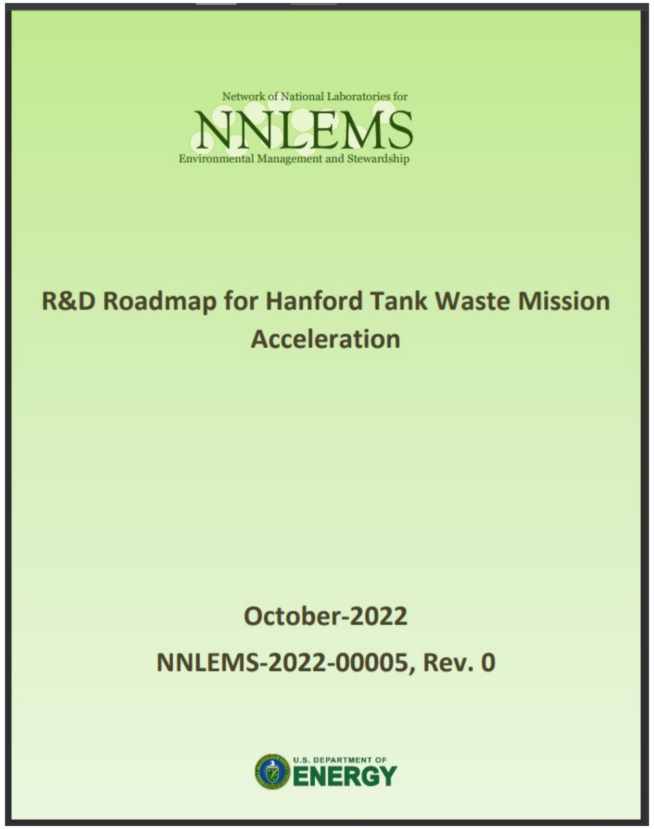
Project Background: DOE-EM issued Lab Call

Awarded: Efficient Electrochemical Denitration and Caustic Generation (EDCGe) System for Direct-Feed Waste Pretreatment to Accelerate the Hanford Mission and Operations (April 2024)

Tasks are directed toward three defined thrusts:

Priority	Concept	R&D Timeframe	Investment Total cost	Estimated Cost Savings	Schedule Acceleration
Top	At-tank pretreatment of HLW Sludge	0–5 yrs.	$100–300M	>$25B	>10 yrs.
High	RCRA organics removal from tank supernate	0–10 yrs.	$10–50M	>$25B	>10 yrs.
Medium	Sodium nitrate separation or destruction technologies	0–15 yrs.	$10–50M	$0–250M	0–3 yrs.

R&D Roadmap for Hanford Tank Waste Mission Acceleration, Oct 2022. NNLEMS-2022-00005, Rev. 0


Network of National Laboratories for
NNLEMS
Environmental Management and Stewardship

R&D Roadmap for Hanford Tank Waste Mission Acceleration

October-2022

NNLEMS-2022-00005, Rev. 0

U.S. DEPARTMENT OF ENERGY

Efficient Electrochemical Denitration and Caustic Generation (EDCGe) System for Direct-Feed Waste Pretreatment at Hanford

Project Leader: Dr. Dylan Rodene (SRNL)

Goal: Remediate nitrate & nitrite anions (& organics) from High level Waste (HLW) supernatant feed at Hanford Melter, which have emission limits

SRNL Focus: Bench-scale and pilot-scale electrochemical reactor design and testing

Collaborators:

Idaho National Laboratory: Reactor system to design & advanced catalysts

Polykala Technologies Inc.: Commercial electrolyzers evaluation for scale-up

University of South Carolina: Catalyst development

Clemson University: Membrane development

North Carolina A&T: Process and reactor modeling

Contact: Dylan.Rodene@srnl.doe.gov

SRNL — Savannah River National Laboratory

INL Idaho National Laboratory

pKa Polykala Technologies

University of South Carolina

Clemson University

North Carolina Agricultural and Technical State University

U.S. Department of Energy

Funding source: DOE-EM Office

Drive for Pretreatment of Direct-Feed High Level Waste Stream

Challenges:

- Settling rate of Nuclear Sludge (distance to WT&IP)
  - ➢ Caustic & Supernatant Required
- Nitrates & organics in Supernatant feed to Waste Treatment Plant
  - ➢ Impact: NO_x and volatile gases generated at melter
- Melter feed specified by Waste Acceptance Criteria
  - ➢ Impact: Scheduling & Batching constraints
- Imminent danger of accidental gas release ⇒ Safety concern

❖ Potential for costly redesign & construction of Off-gas system

https://www.hanford.gov/files.cfm/Tank_Farm_Overview_Fact_Sheet.pdf

Concept:

- A novel electrochemical denitration & organic oxidations skid tank-side facility
- Skid Off-Gas Oxidation of Ammonia & Organics to N_2 & CO_2.
- On-site Caustic production (sludge mobilization)

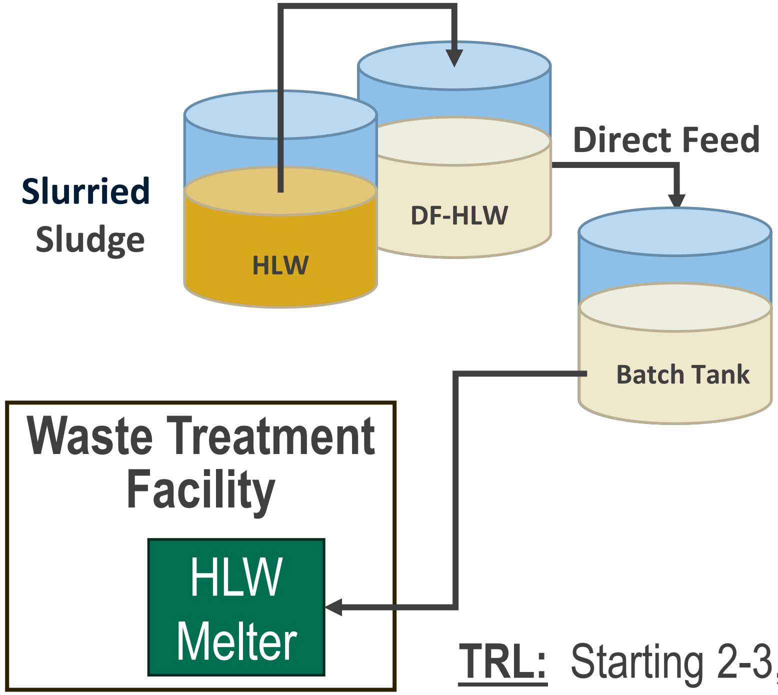
❖ Removal of nitrates & organics in waste to enable processing in WT&IP

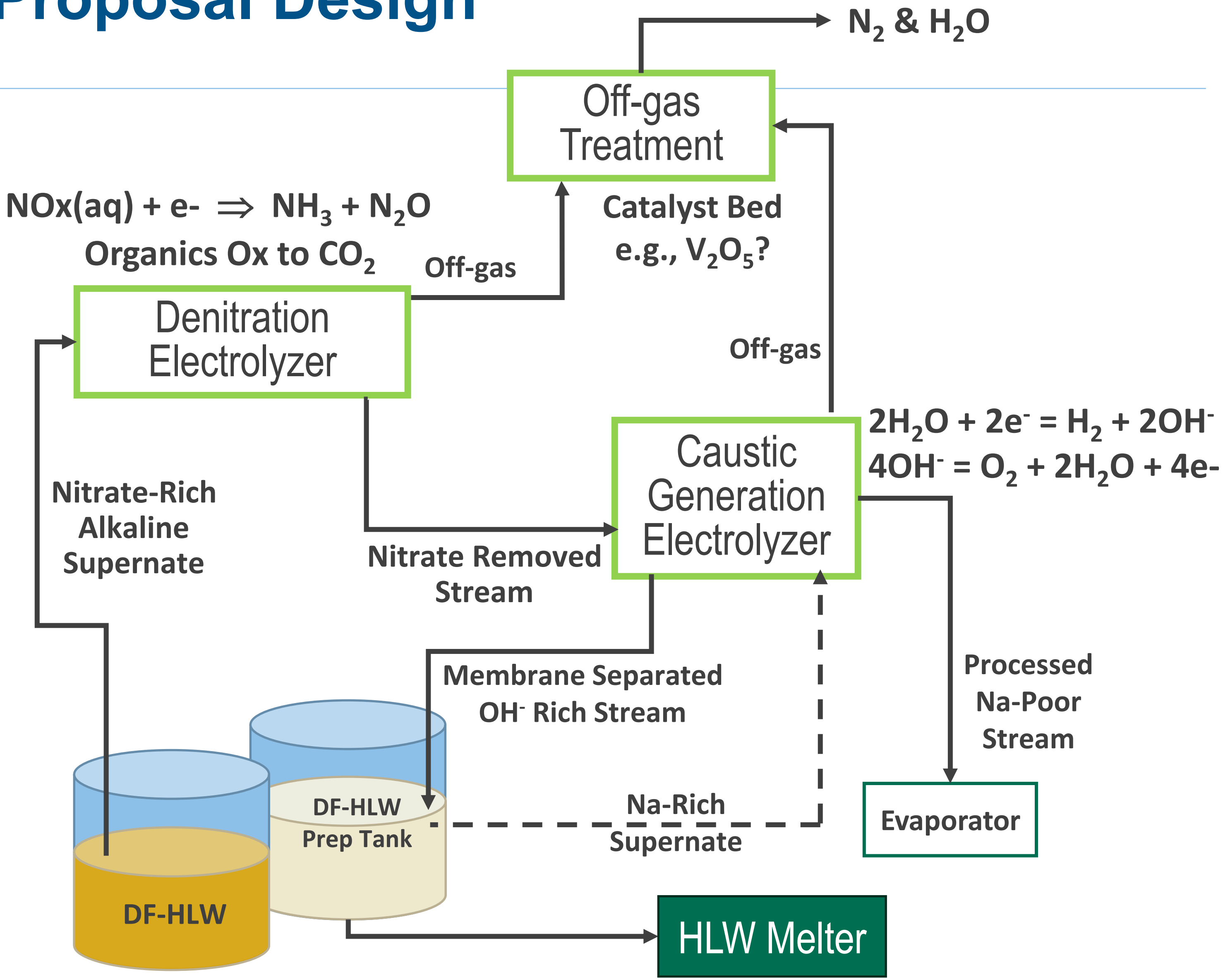
EDCGe System: Preliminary Proposal Design

Process will treat the waste by:

- Removing Nitrate (NO_3^-)/Nitrite (NO_2^-)
- Producing caustic (to mobilize sludge)
- Abating organics

Direct Feed-HLW Process





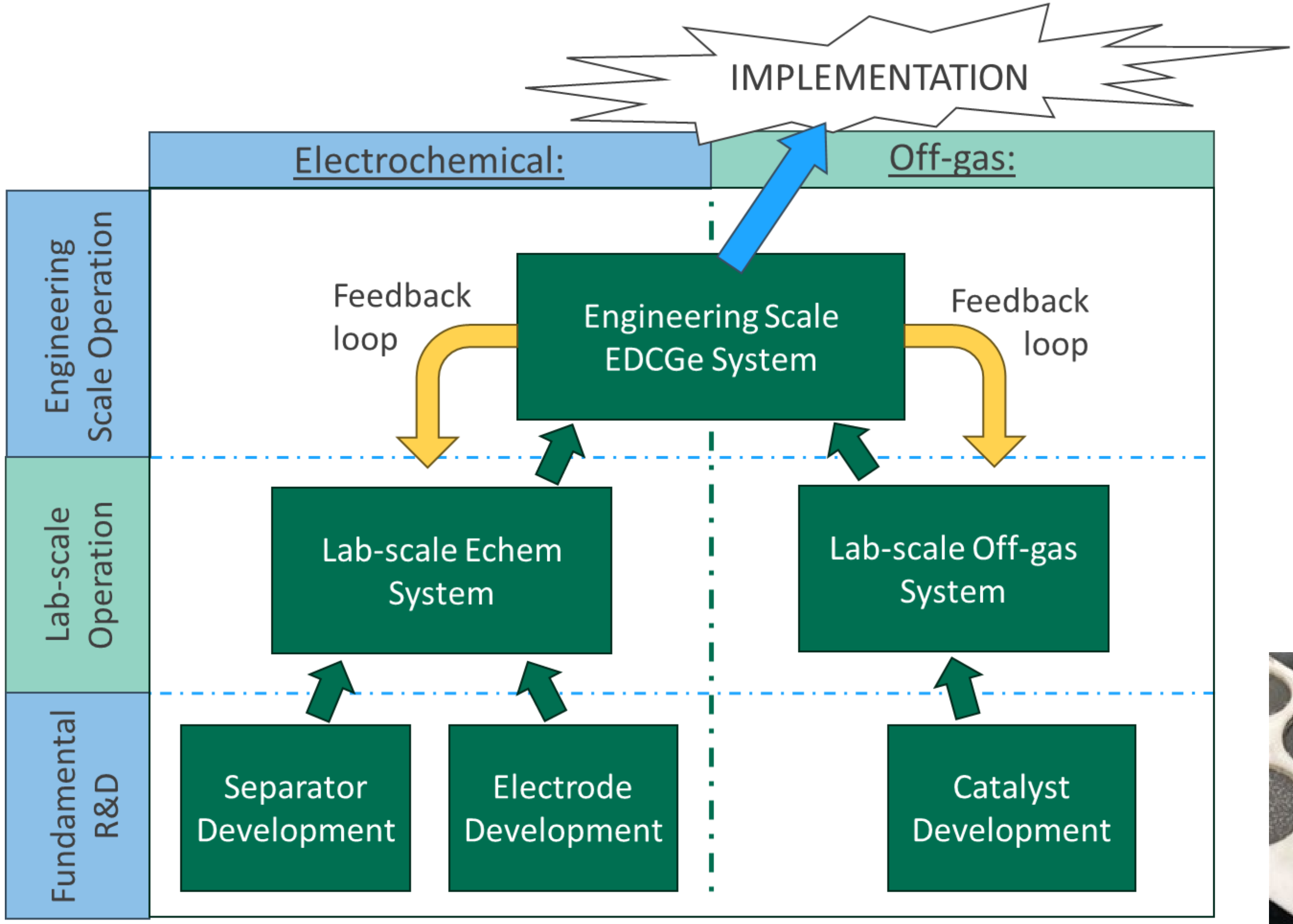
TRL: Starting 2-3, Final 4-5

Project Layout & Structure:

Engineering scale flow cell

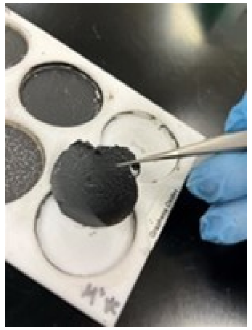
Electrochemical flow cell

Electrochemical H-cell



TRL: Starting 2-3, Final 4-5

Off-gas reactor furnace



High Entropy Alloy Catalyst

Challenges and Implementation Considerations at Hanford

Key Implementation Considerations:

- Catalyst Development for Denitration and Off-gas Processing (Commercial partners for scaleup)
- Alternative to Nafion Membrane for Denitration and Caustic Generation (Commercial engineering partner for scaleup.)
- Formation of byproducts is dependent on selectivity & efficiency of denitration electrolyzer. Will impact Capital & Operating Costs.

❖ Tri-Party Agreement: U.S. DOE, Environmental Protection Agency & Washington State Department of Ecology signed a comprehensive cleanup and compliance agreement

  - Provides guidance & Defines CERCLA & RCRA cleanup commitments
  - Establishes responsibilities & Provides a basis for budgeting
  - Concerted goal of achieving regulatory compliance and remediation, with enforceable milestones

❖ Activities of the DOE Subcontractors for Tank Farm Operations & Facility Construction is defined by Contracts that could drive solutions in alternative directions

Citation: https://www.hanford.gov/page.cfm/TriParty

Advanced Manufacturing Collaborative (New SRNL DOE Facility)

U.S. DEPARTMENT of ENERGY | Office of Environmental Management

$65 million & 60,000 sf

- Developing Technology
- De-risking Adoption
- Enabling Deployment
- Building Partnerships

SRNL cornerstone capability for

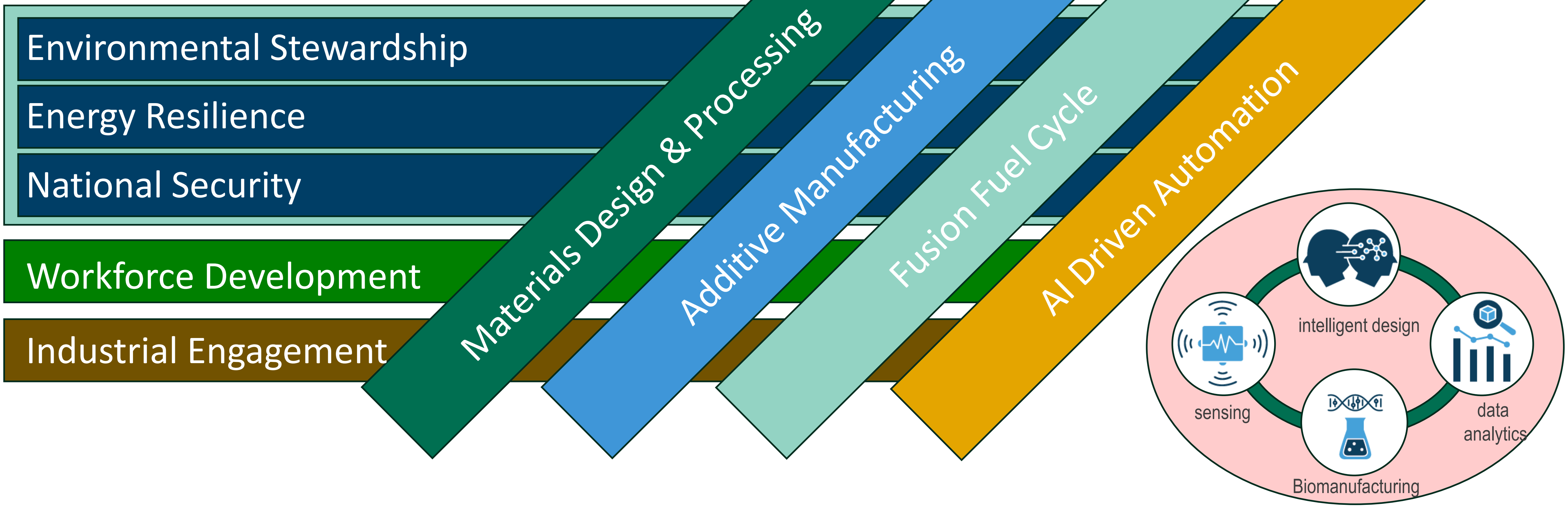
Creating manufacturing solutions for national security, environmental stewardship, and energy resilience

Daren J. Timmons, PhD
Director, Technology Partnerships and the Advanced Manufacturing Collaborative

AMC Scope & Engagement Areas

- Enabling manufacturing innovation
- Catalyzing commercialization

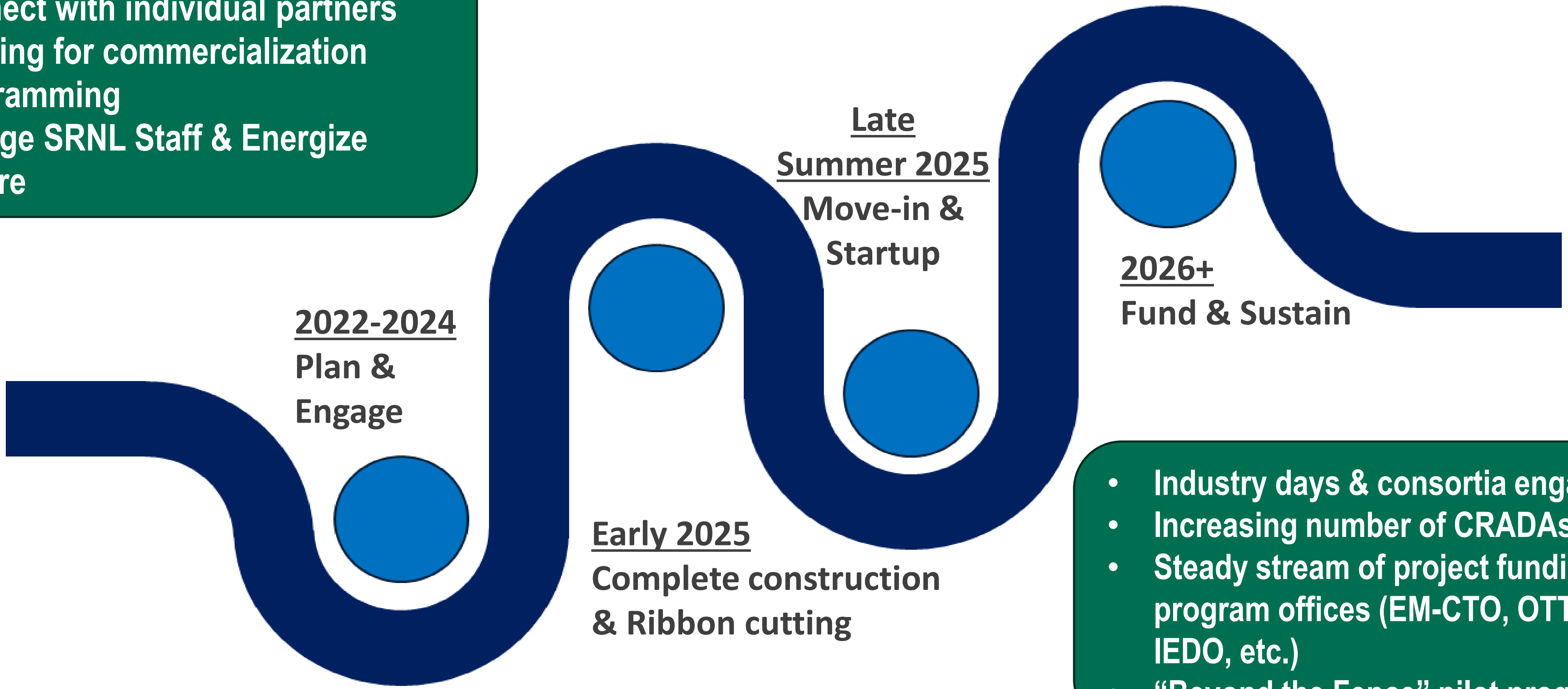
AMC Mission: Advance environmental stewardship, energy resilience, national security, and manufacturing innovation through public-private partnerships built on SRNL expertise in separations and materials sciences.



AMC Roadmap

- Enabling manufacturing innovation
- Catalyzing commercialization

- Initial research programming
- Connect with individual partners
- Funding for commercialization programming
- Engage SRNL Staff & Energize culture



- Industry days & consortia engagements
- Increasing number of CRADAs/SPP-NFEs
- Steady stream of project funding from DOE program offices (EM-CTO, OTT, AMMTO, IEDO, etc.)
- "Beyond the Fence" pilot program

Thank you!

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