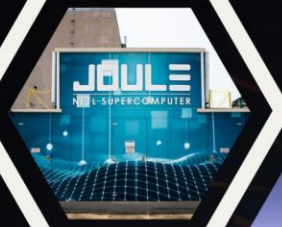
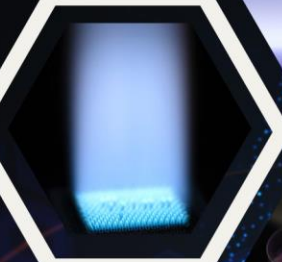



NETL OVERVIEW

De-risking and Scaling Technologies for a Net-Zero Energy Future

Brian J. Anderson, Ph.D.
Director
National Energy Technology Laboratory
U.S. Department of Energy

2023 FECM / NETL Spring R&D Project Review Meeting
April 18, 2023




U.S. DEPARTMENT OF ENERGY | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Supporting DOE Priorities

Enabling the Transformation to a Net-Zero Energy Future

Investing in Domestic Clean Energy Manufacturing

Advancing Environmental Justice

Tackling the Climate Crisis

NETL Supports FECM's Strategic Vision

Advancing Carbon Management Approaches Toward Deep Decarbonization

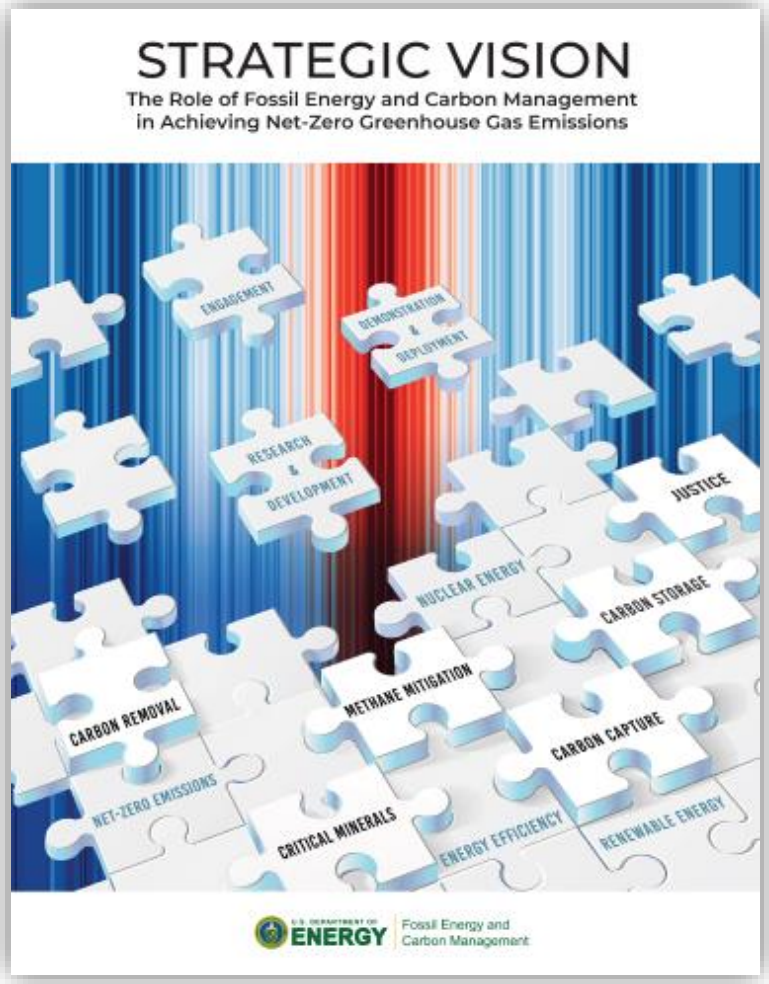
- Point-source carbon capture
- Carbon dioxide conversion
- Carbon dioxide removal
- Reliable carbon transport and storage

Advancing Technologies that Lead to Sustainable Energy Resources

- Hydrogen with carbon management
- Domestic critical minerals production

Advancing Justice, Labor, and Engagement

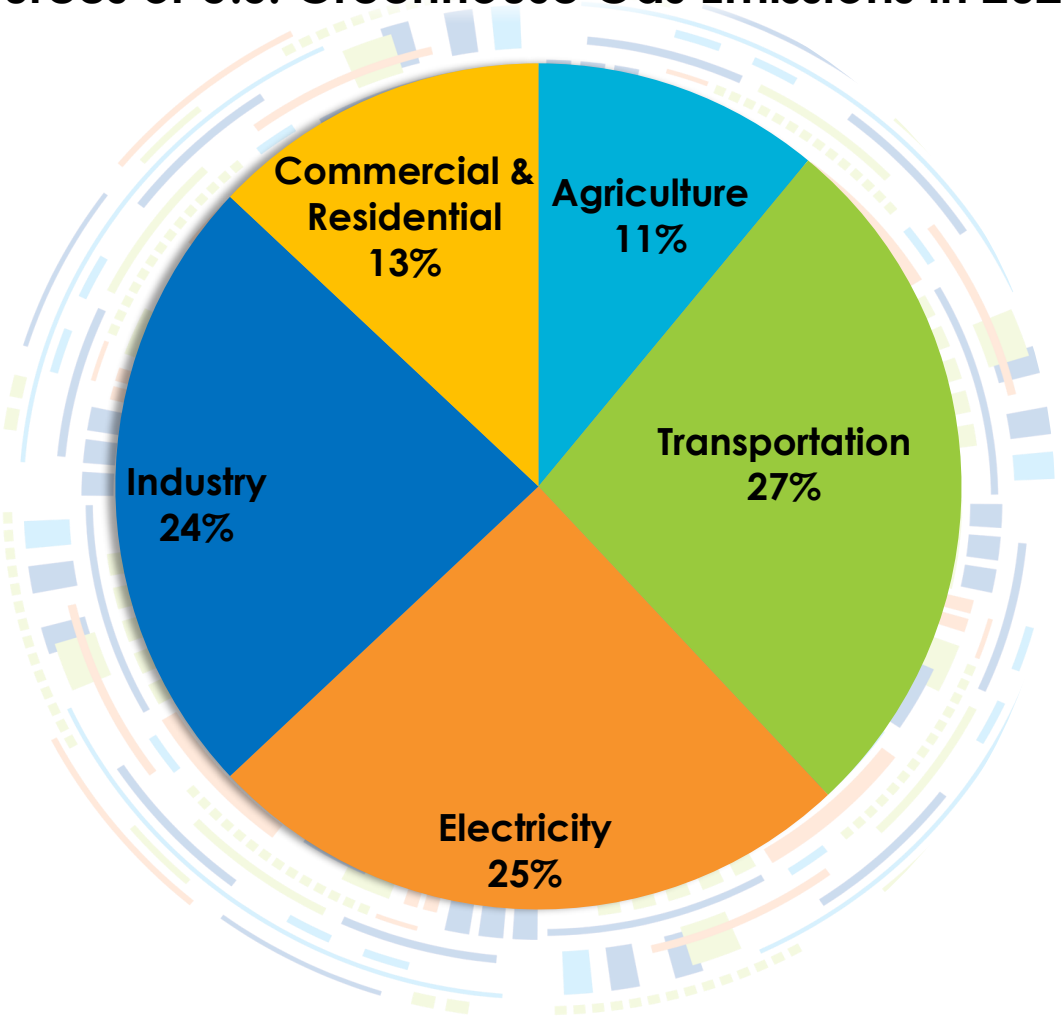
- Justice
- Labor
- International and Domestic Partnerships



Transitioning to a Carbon-free Economy

- President Biden's goals:
  - 50% emissions reduction by 2030
  - CO_2 emissions-free power sector by 2035
  - Net-zero emissions economy by 2050
- Innovative carbon management technologies will drive the energy transition.
- We must look at every sector to achieve climate goals.
- We must also incorporate environmental justice, equity, and workforce development at the center of our work.

Sources of U.S. Greenhouse Gas Emissions in 2020



All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*.

The National Energy Technology Laboratory

Organization Snapshot

MISSION

Driving innovation and delivering solutions for an environmentally sustainable and prosperous energy future:

- Ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while
- Developing technologies to manage carbon across the full life cycle, and
- Enabling environmental sustainability for all Americans.

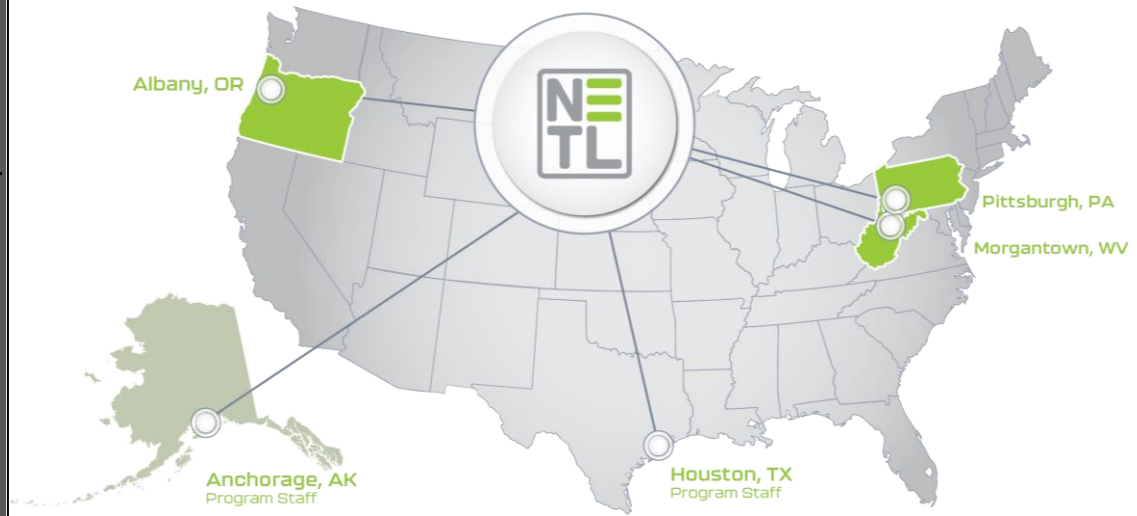
VISION

To be the nation's premier energy technology laboratory, delivering integrated solutions to enable transformation to a sustainable energy future.

MAJOR INITIATIVES

- **Decarbonization & Carbon Management**
- **Environmentally Sustainable Supply Chains**
- **Integrated Energy & Industrial Systems**
- **Advanced Data & Computing Solutions for Applied Energy Challenges**

3 RESEARCH LABS & 2 STRATEGIC OFFICES



- One of 17 DOE national laboratories
- One of three applied research national labs
- Government owned & operated
- **1000+** R&D projects in 50 states
- **$5.0B** total award value
- **$1.3B** FY23 budget

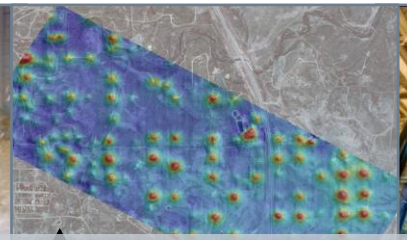
IMPLEMENTS R&D PROJECTS FOR DOE'S OFFICES OF:

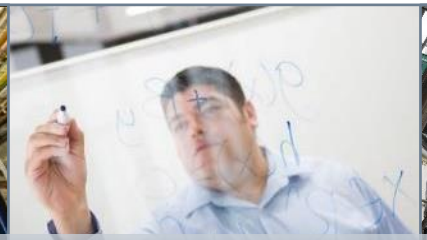
- Fossil Energy & Carbon Management
- Energy Efficiency Renewable Energy
- Electricity
- Cybersecurity, Energy Security, & Emergency Response
- Manufacturing, & Energy Supply Chains
- Grid Deployment
- Clean Energy Demonstrations

Core Competencies & Technology Thrusts

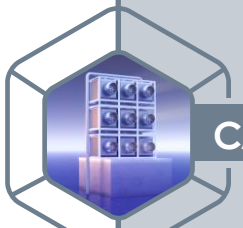
NATIONAL ENERGY TECHNOLOGY LABORATORY








Computational Science & Engineering | Materials Engineering & Manufacturing | Geological & Environmental Systems | Energy Conversion Engineering | Strategic Systems Analysis & Engineering | Program Execution & Integration



CARBON MANAGEMENT

Carbon Capture

Carbon Dioxide Removal

Carbon Utilization

Carbon Transport & Storage

Hydrogen with Carbon Management

Crosscutting Research


RESOURCE SUSTAINABILITY

Decarbonization of Natural Gas Resources

Methane Mitigation Technology

Advanced Remediation Technologies

Critical Minerals & Materials

Methane Hydrates


OTHER DOE OFFICES

Energy Efficiency & Renewable Energy

Vehicles

Buildings

Adv Manufacturing

Geothermal

Hydrogen & Fuel Cell


Office of Electricity

Adv Grid R&D

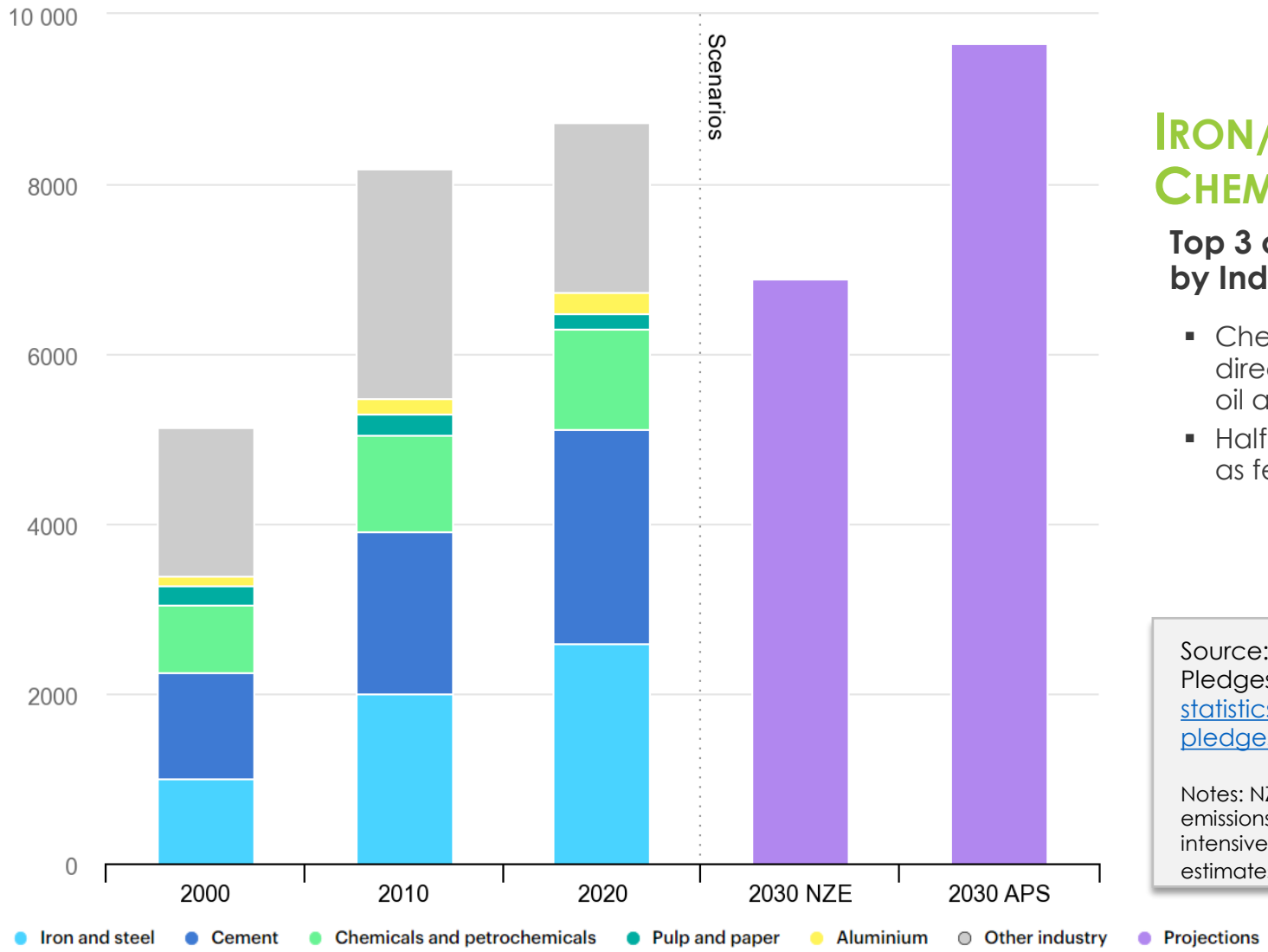
Energy Resilience


Cybersecurity, Energy Security, & Emergency Response

Security & Restoration

Cybersecurity


Industry Direct CO_2 Emissions – IEA Projection



Iron/Steel, Cement, and Chemical/Petrochemicals

Top 3 contributors to direct CO_2 Emissions by Industry for over 20 years

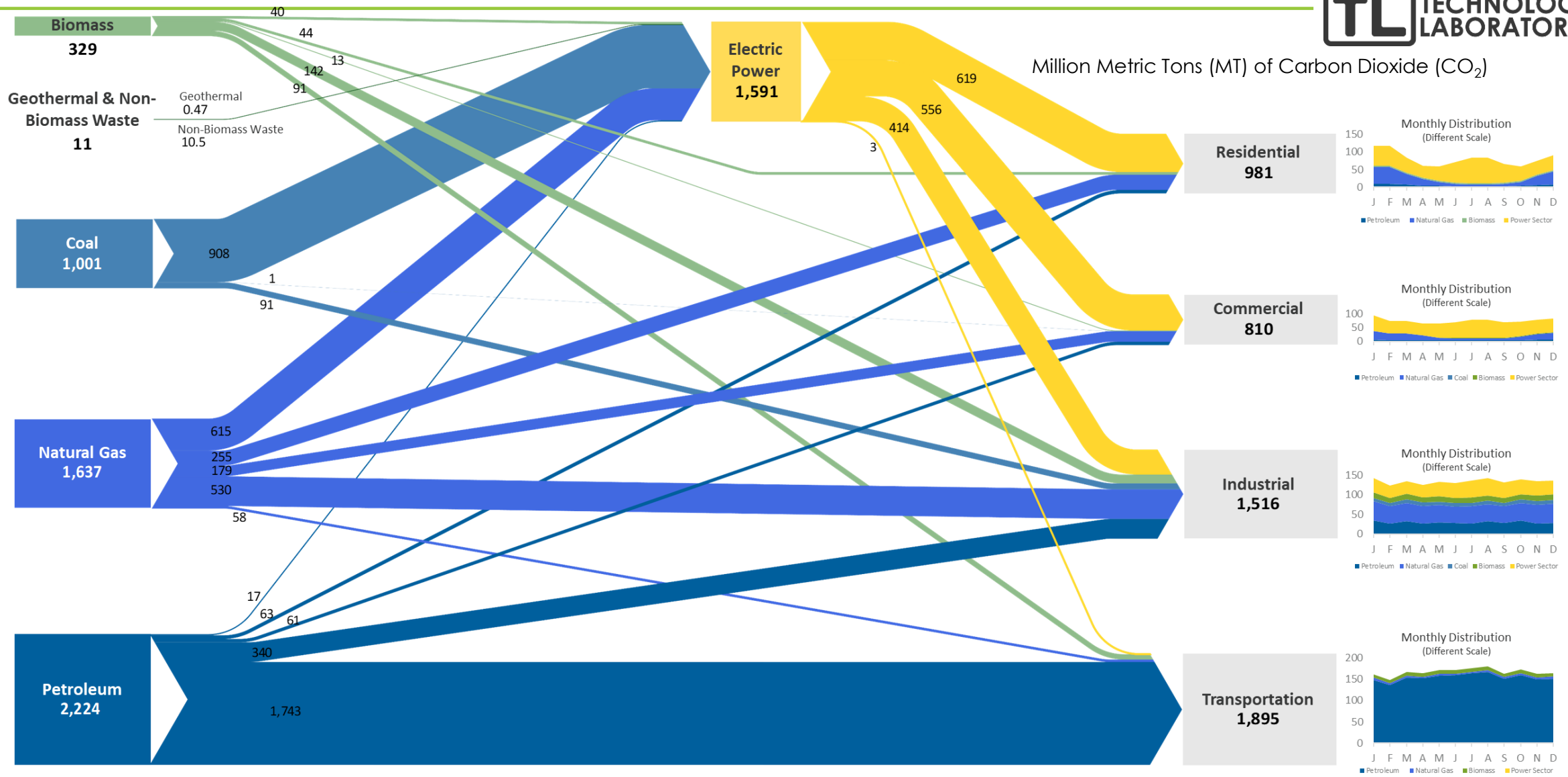
- Chemical industry is third leading industry subsector in direct CO_2 emissions but the largest industrial consumer of oil and gas[1]
- Half of the chemical subsector's energy output consumed as feedstock

Source: IEA, Industry direct CO2 emissions in the Net Zero and Announced Pledges scenarios, 2000-2030, IEA, Paris. https://www.iea.org/data-and-statistics/charts/industry-direct-co2-emissions-in-the-net-zero-and-announced-pledges-scenarios-2000-2030

Notes: NZE = Net Zero Emissions Scenario. APS = Announced Pledges Scenario. Direct CO2 emissions encompass energy and process emissions. "Other industry" includes non-energy-intensive industries such as food and beverages, mining, and textiles. Values for 2020 are estimates.

[1] IEA (2021), Chemicals, IEA, Paris https://www.iea.org/reports/chemicals

Estimated U.S. Energy-Related CO_2 Emissions in 2021: 5,202 MT



Metric Ton = 1.1023 U.S. short Ton

Metric Tons of Carbon Dioxide to Carbon Equivalent multiply by 12/44

General CO_2 Emissions Coefficients
(Metric Ton of CO_2 per Quadrillion Btu)
Coal: 94.6 Natural Gas: 53.9 Petroleum: 74.5

Reference: DOE/EIA-0035(2022/04)

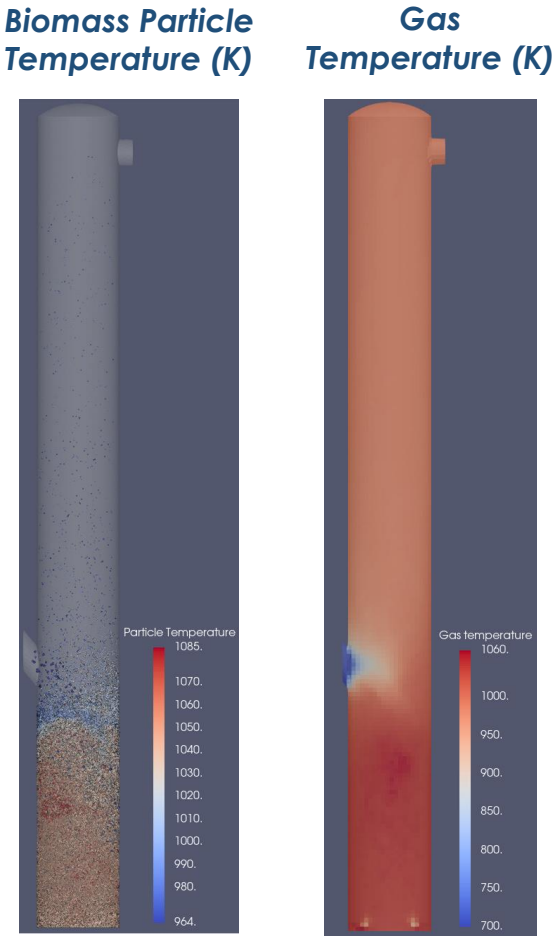
SSAE 5/2/2022

Gasification Systems

Program: Developing gasification & supporting technologies to enable the use of diverse waste & biomass feedstocks to produce hydrogen and other value-added products with net-zero carbon emissions

RIC Focus:

- Advanced reactor design (MFiX)
- Refractory materials for multi-fuel gasification
- Oxygen carriers & air separation processes
- Microwave reactions for gasification processes
- Disposition of wastes by gasification for a circular economy
- Economical clean hydrogen production



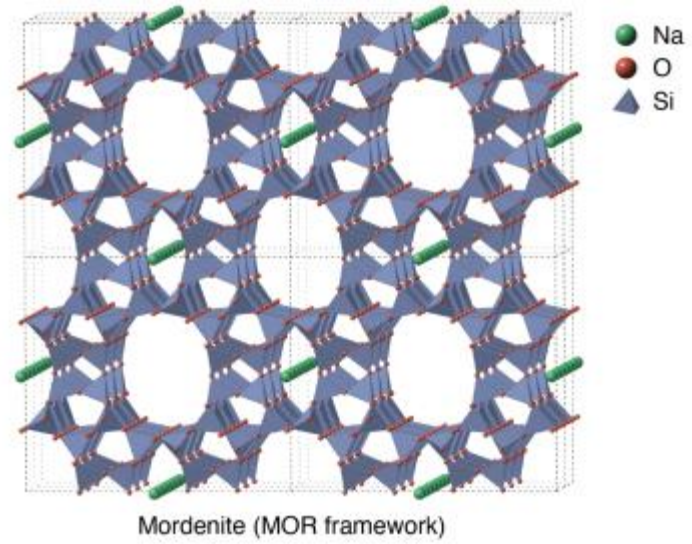
MFiX Model of Fluidized Gasification Reactor located at Sotacarbo, Italy

Emissions Control

Program: Developing technologies to reduce generation, increase beneficial utilization, and improve the environmental performance of long term storage of coal combustion residuals/ash

RIC Focus:

- Development of AI/ML-based computational design of customized zeolite sorbents for ash impoundment wastewater treatment
- Gainful utilization of legacy ash as feedstock for sorbent synthesis
- Experimental testing of sorbents



Microscopic structure of a zeolite (mordenite) framework

Reversible Solid Oxide Fuel Cells (rSOC)

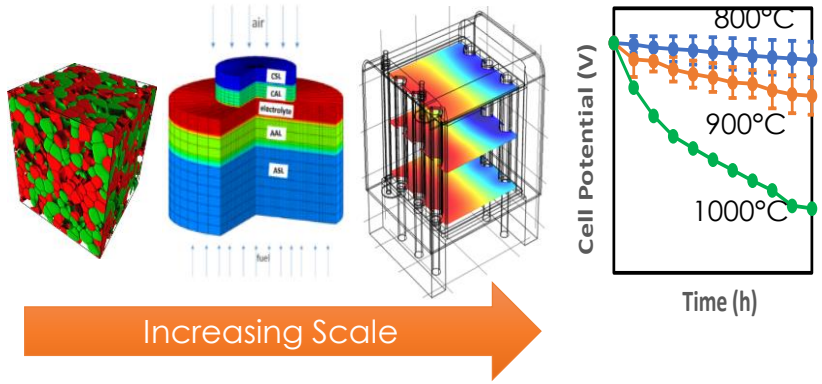
Program: Research, development, and demonstration to enable electricity generation in a highly efficient, cost-effective method with near-zero atmospheric emissions of carbon dioxide

RIC Focus:

- Cell and Stack Degradation Evaluation and Modeling
- Electrode Engineering
- Systems Engineering and Analysis
- Cyber Physical Modeling
- H2NEW Consortium: High Temp Electrolyzers
- UND-EERC: Coal Syngas Cleanup for Commercially Viable SOFC Performance (UND, NETL, CMU, WPI, Ohio Fuel Cell Consortium)
- 6-kW SolydEra SOFC Demonstration at NETL Morgantown

Performance Degradation Modeling

- Degradation prediction tools
- Atoms-to-System scale bridging
- Experimental validation
- Advanced Gas, Temperature Sensors



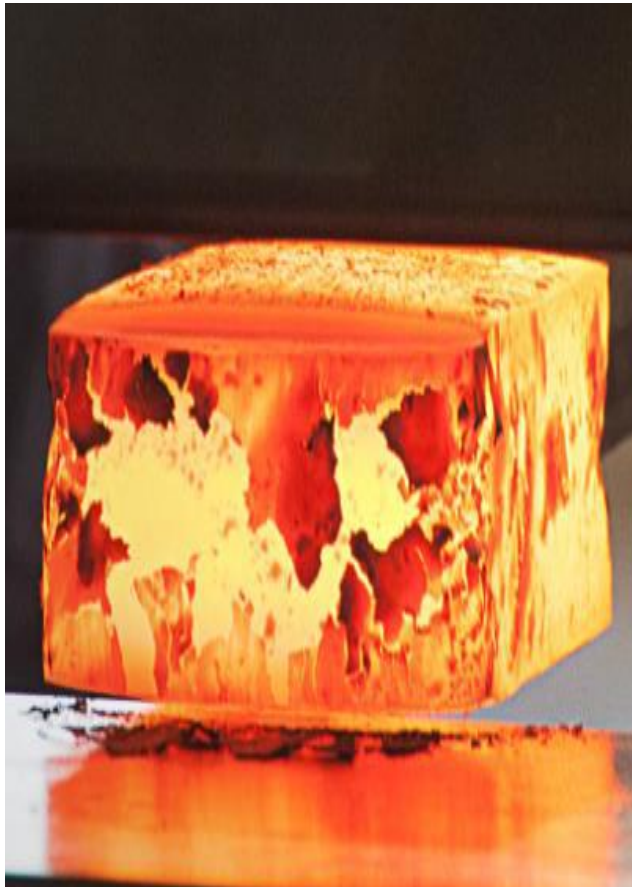
Advanced Energy Materials

Program:

- Evaluating impacts of hydrogen on material to establish a new domestic supply chain of hydrogen resistant materials
- Enhancing the nation's supply chain for high-temperature materials to support a competitive U.S. industry base and create a skilled workforce
- Develop Ceramic Matrix Composite (CMC) materials for turbines to address 70% efficiency and turbines firing 100% hydrogen

RIC Focus:

- NETL-RIC and ORNL coordinated & collaborative research focused on understanding HTHA in alloys and weldments
- Research and development of cost-effective steels, Ni-superalloys, novel High Entropy Alloys & coatings
- NETL-Led eXtremeMAT National Laboratory Collaboration R&D to develop materials and component life prediction models in hydrogen service at elevated temperatures and long service times
- NETL-RIC and ORNL coordinated & collaborative research focused on understanding impact alloy microstructures produced via advanced manufacturing on materials for hydrogen service
- NETL-RIC alloy development R&D for cost-effective Ni- alloys to accommodate use of CMCs and higher combustion temperatures associated with H2 turbines



Energy Asset Transformation (EAT)

Program Focus: Transforming abandoned fossil energy assets using storage

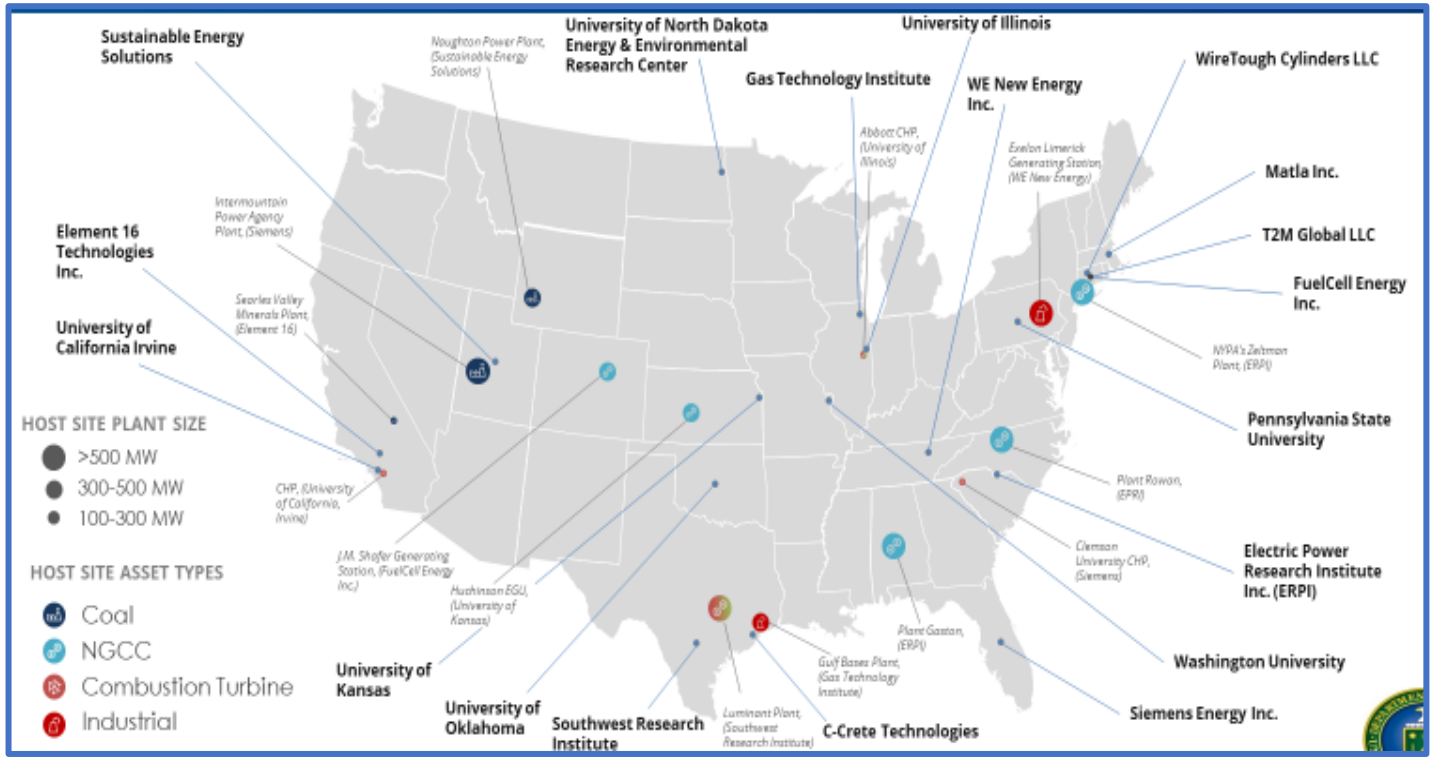
Program Mission:

- Asset flexibility
- Grid reliability
- Environmental performance

Program Benefits:

- Reliable & affordable
- Cleaner environment
- Stronger infrastructure

PORTFOLIO PARTICIPANTS

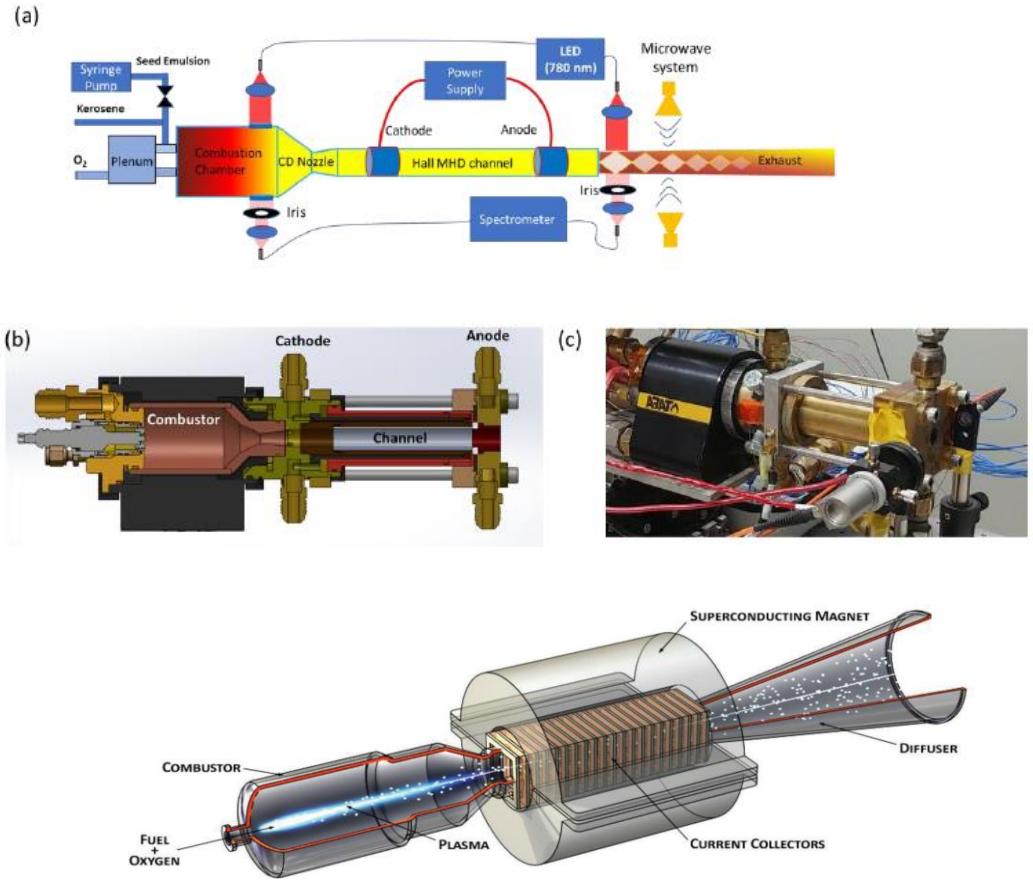


Sensors and Controls

Program: Enabling complex, integrated FECM-relevant applications for optimal process performance, reliability, and environmental integrity

RIC Focus:

- Field testing of raman gas analyzer (RGA)
- Optical fiber sensors for harsh fossil energy environments
- Development of laser-induced breakdown spectroscopy for specialized fossil energy applications
- Direct power extraction (DPE)
- Visible light communications (VLC)/ light fidelity (Li-Fi) and sensors for secure, wireless alternative



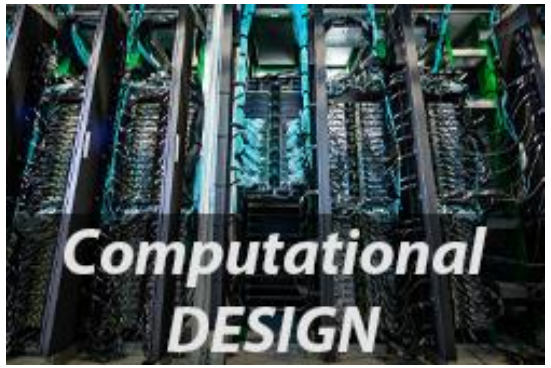
Early-stage R&D project is investigating and testing MHD power generation concepts for future fossil-derived electrical power generation with and without carbon capture.

Simulation-Based Engineering

Program: Developing new innovative models and computational tools for clean fossil energy technologies

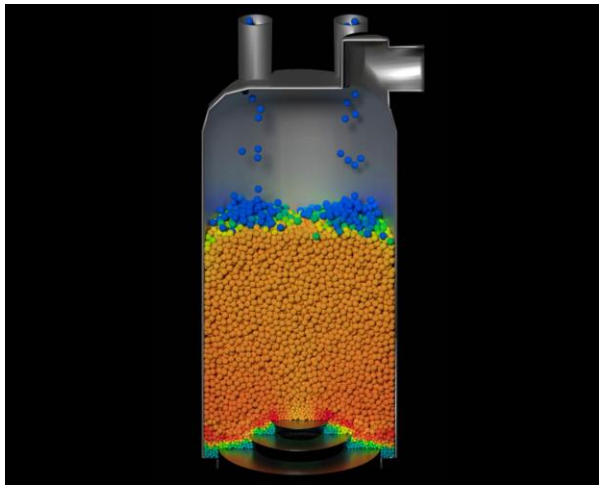
RIC Focus:

- The Institute for the Design of Advanced Energy Systems (IDAES)
- eXtremeMAT: Accelerated design and manufacture of next generation extreme environment materials
- Advanced reaction systems
- CFD for advanced reactor design (CARD)



MFiX

IDAES
Institute for the Design of Advanced Energy Systems

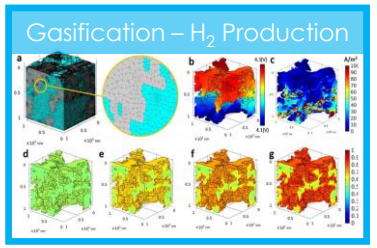


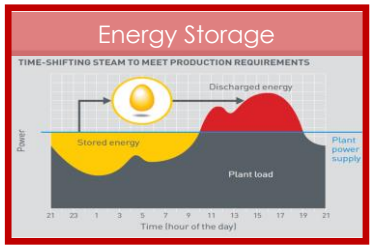
University Training & Research

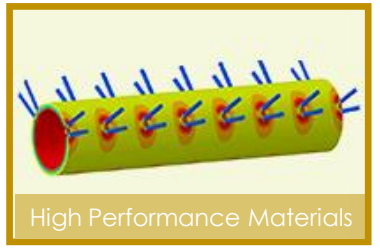
Program: Preparing the next generation to meet future energy challenges

Focus:

- Educate and train the next generation of engineers and scientists
- Support novel, early-stage research that advances FECM's mission of delivering integrated solutions related to fossil energy and carbon management
- Increase R&D opportunities for underrepresented and structurally marginalized communities
- Ensure that students are being equipped with cutting-edge, translatable skillsets







Established & Expanding Partnerships

An Active Portfolio from Concept to Market Readiness

600+ partnerships with industry, academia, and gov't agencies

1000+ research and development projects nationwide

Partnering with NETL

- Cooperative Research and Development Agreement (CRADA)
- Contributed Funds-In Agreement (CFA)
- Memorandums of Understanding (MOU)/ Memorandums of Agreement (MOA)
- Interagency Agreements (IAA)
- Interinstitutional Agreements (IIA)
- Small Business Innovation Research (SBIR) & Small Business Technology Transfer (STTR) Programs
- Unsolicited Proposals (USP)
- Non-disclosure Agreement (NDA)
- Funding Opportunity Announcement (FOA)

Available Technologies

- NETL's technology portfolio contains a broad range of innovations that have resulted from research
- Technologies and intellectual property available for licensing on NETL's website

Available Technologies:
https://www.netl.doe.gov/business/tech-transfer/available-technologies

Funding Opportunity Announcement (FOA)

- NETL uses FedConnect.net, Grants.gov and SAM.gov to post FOAs
- Proposals and applications are only accepted electronically through FedConnect.net or Grants.gov

Funding Opportunities:
https://www.netl.doe.gov/business/solicitations

Thank You!

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