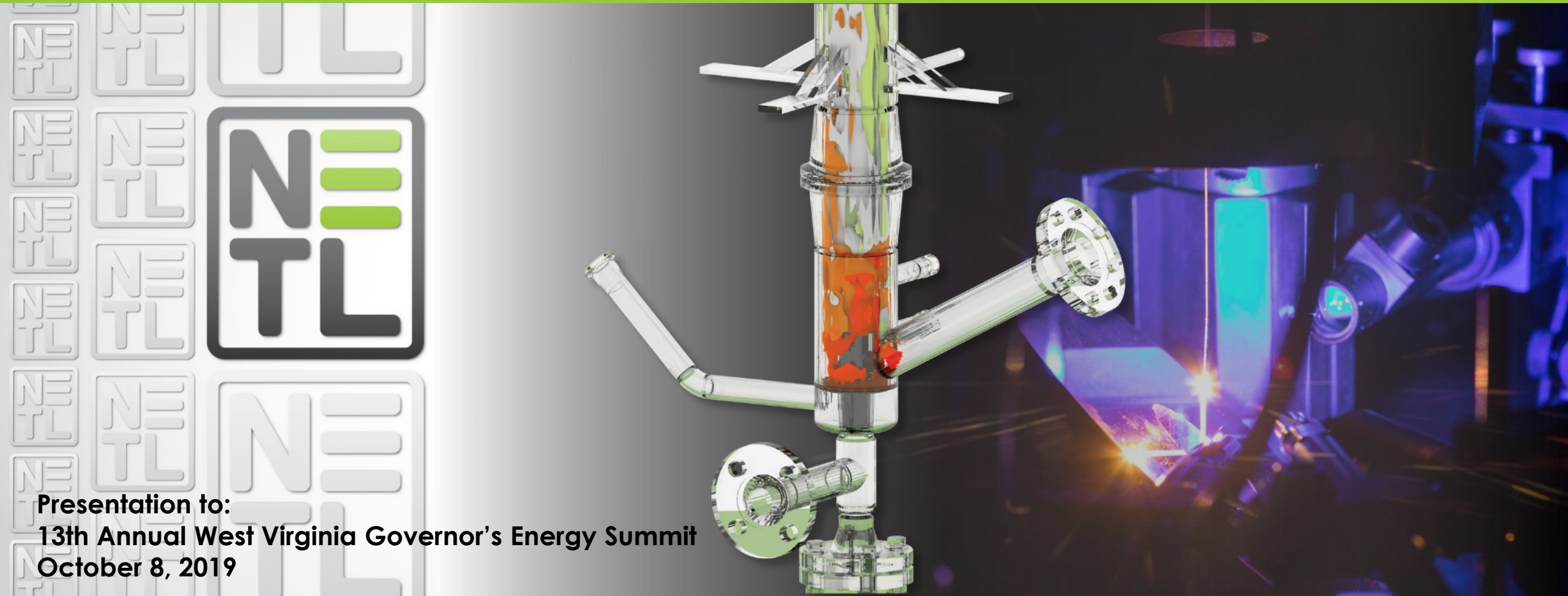


Driving the Technology Innovation Ecosystem through Applied Research and Collaboration

Solutions for Today | Options for Tomorrow



Brian J. Anderson, Ph.D.
Director



Presentation to:
13th Annual West Virginia Governor's Energy Summit
October 8, 2019

MISSION

Discover, integrate and mature technology solutions to enhance the Nation's energy foundation and protect the environment for future generations

- **Effective Resource Development**
- **Efficient Energy Conversion**
- **Environmental Sustainability**

VISION

Be the Nation's renowned fossil-energy science and engineering resource, delivering world-class technology solutions today and tomorrow

- **Technology Convener**
- **Knowledge and Technology Generation Center**
- **Responsible Steward**

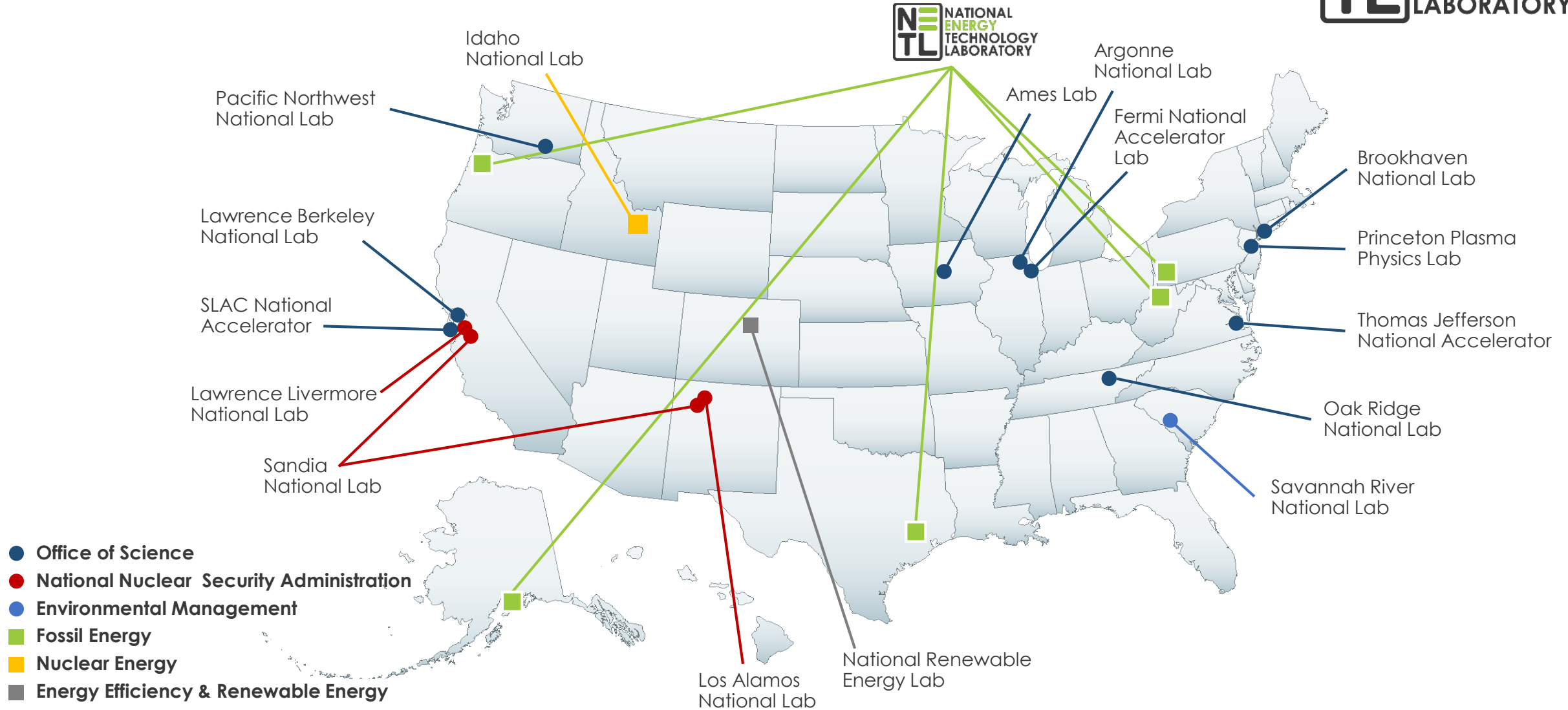


U.S. DEPARTMENT OF
ENERGY



NATIONAL
ENERGY
TECHNOLOGY
LABORATORY

The National Laboratory System



By the Numbers

3 labs across U.S.

900+ R&D projects in **50** states

\$6.3B total award value

\$991M FY19 budget

Workforce

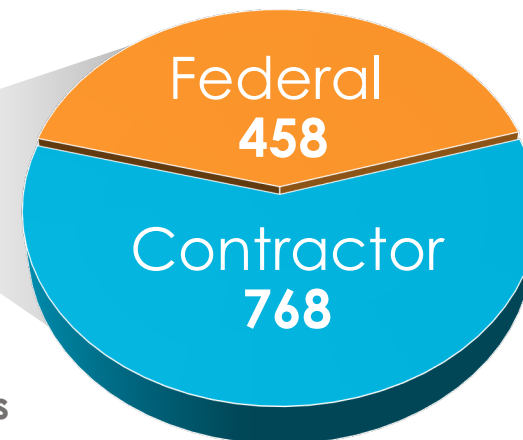
1,226 Full Time Equivalent Employees (FTEs)

70 Joint Faculty

109 Postdoctoral Researchers

54 Graduate Students

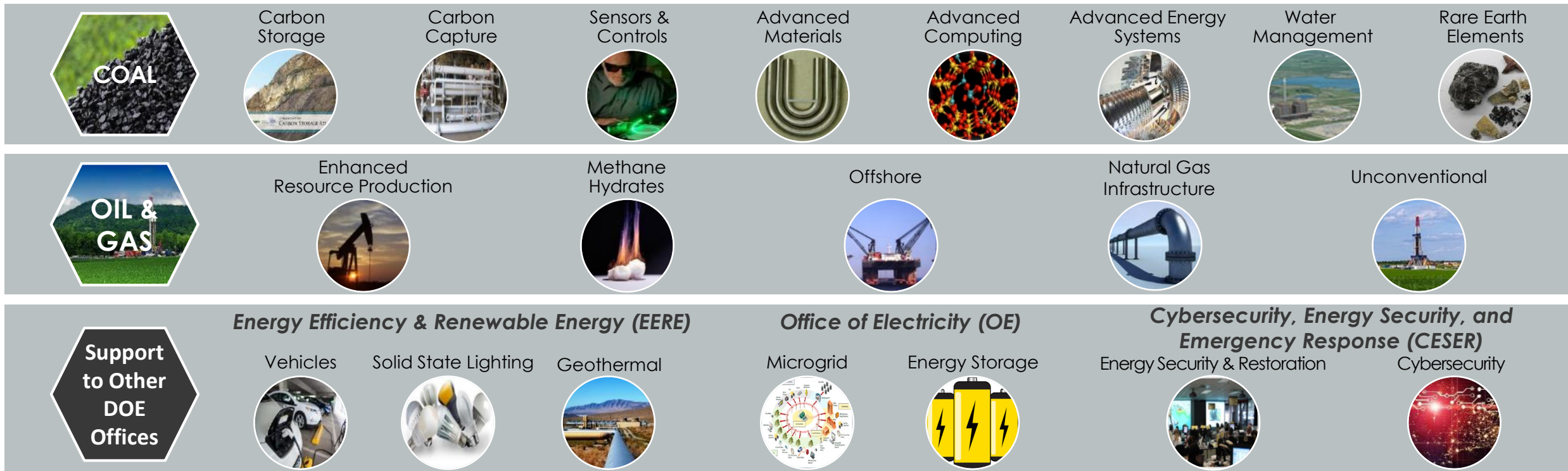
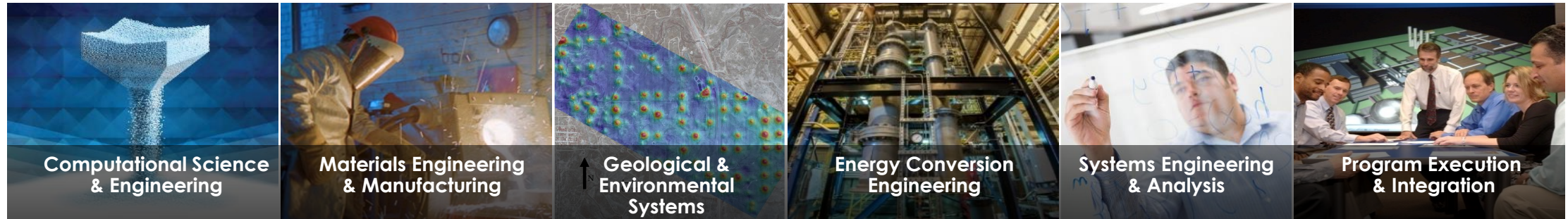
40 Undergraduate Students



NETL possesses an array of authorities to manage & implement complex R&D programs

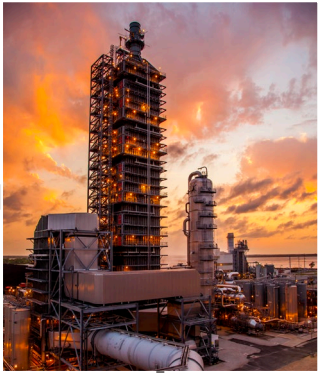
- Program planning, development, and execution
- Legal, Financial, Procurement and Head of Contracting Authority (HCA)
- Project Management Expertise

Core Competencies & Technology Thrusts



Evolving Topics in Coal

Upgrading the Existing Fleet



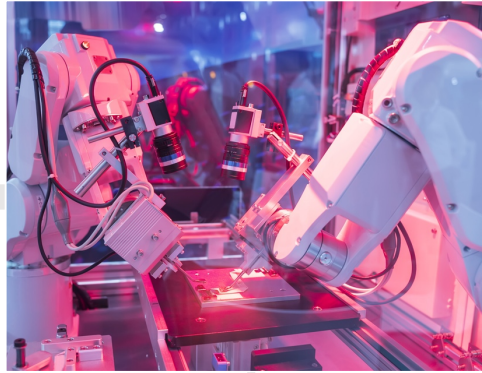
Improving the performance, reliability, & efficiency of the existing coal-fired fleet

Advancing Next-Gen Power Plants



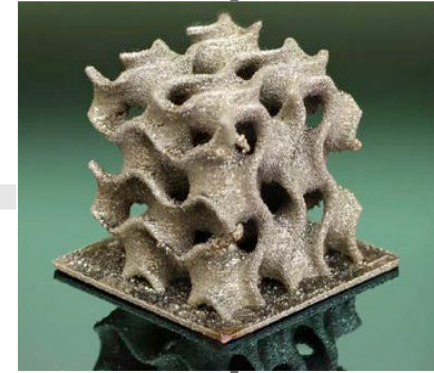
Advancing small-scale, modular coal plants that are highly efficient, flexible, & near-zero emissions

Pioneering New Markets for Coal



Enhancing the value of coal as a feedstock & deriving new value-added products from coal

Reducing the Cost of Carbon Capture



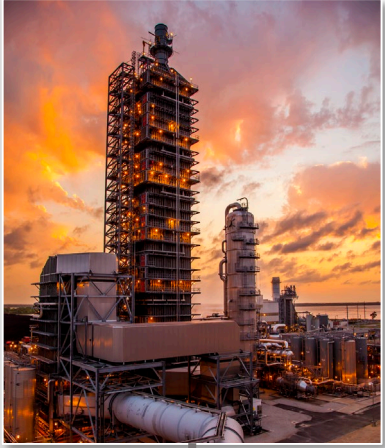
Developing advanced computational & simulation tools, & transformational technologies to reduce the cost of CO₂ capture

Reducing Water Use in Energy Production



Addressing water quality, sustainability, & availability for power generation

Upgrading the Existing Fleet



Improving the
performance,
reliability, &
efficiency of the
existing coal-
fired fleet

NETL Focus Areas

- Sensors, Diagnostics, and Controls to Improve Prediction, Performance, and Reliability
- Power Plant Component Improvement
- Data Analytics Driven Controls

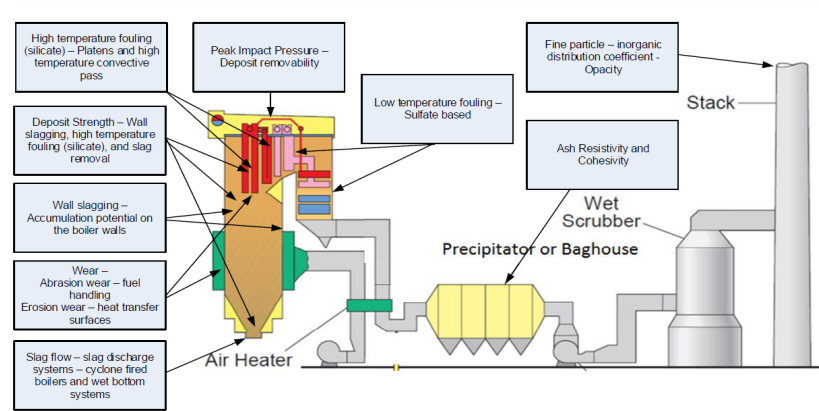
Wireless Sensors for Improved Condition-Based Monitoring



- With sponsorship by NETL, University of Maine developed harsh environment sensing technology and installed a prototype at Longview Powerplant
- Surface acoustic wave sensors are able to operate wirelessly inside a furnace up to around 1000°C.
- Technology offers advantages for inline monitoring of coal-based power generation systems including accurate, battery-free, maintenance-free wireless operation.

Machine Learning in Energy Conversion

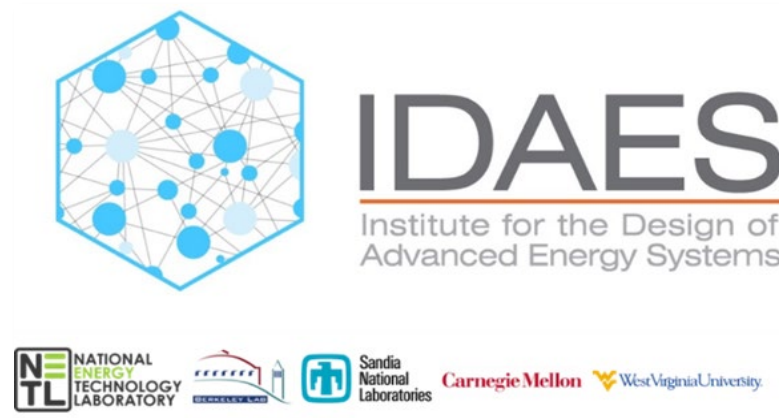
Process Control & Fault Diagnostics



Microbeam Technologies, Inc.

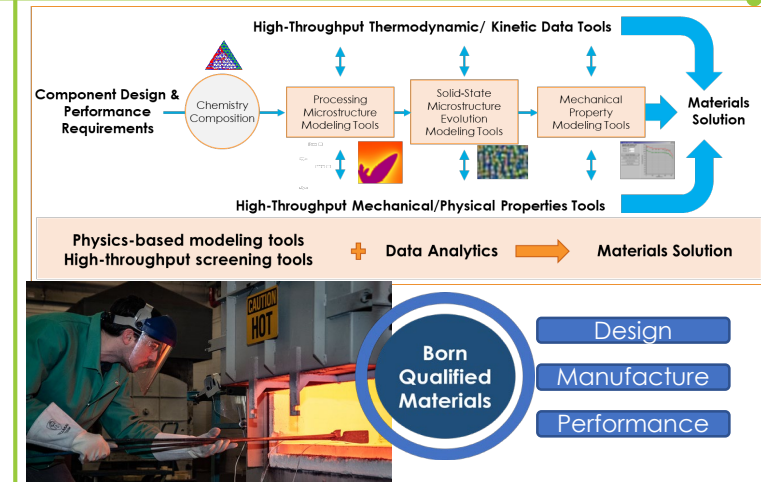
Develop real-time health monitoring for gas turbines and predictive maintenance techniques

Process Synthesis, Optimization, & Intensification



Using machine learning to identify data as input for models and accelerating innovation, prioritize R&D at low TRLs, multi-scale

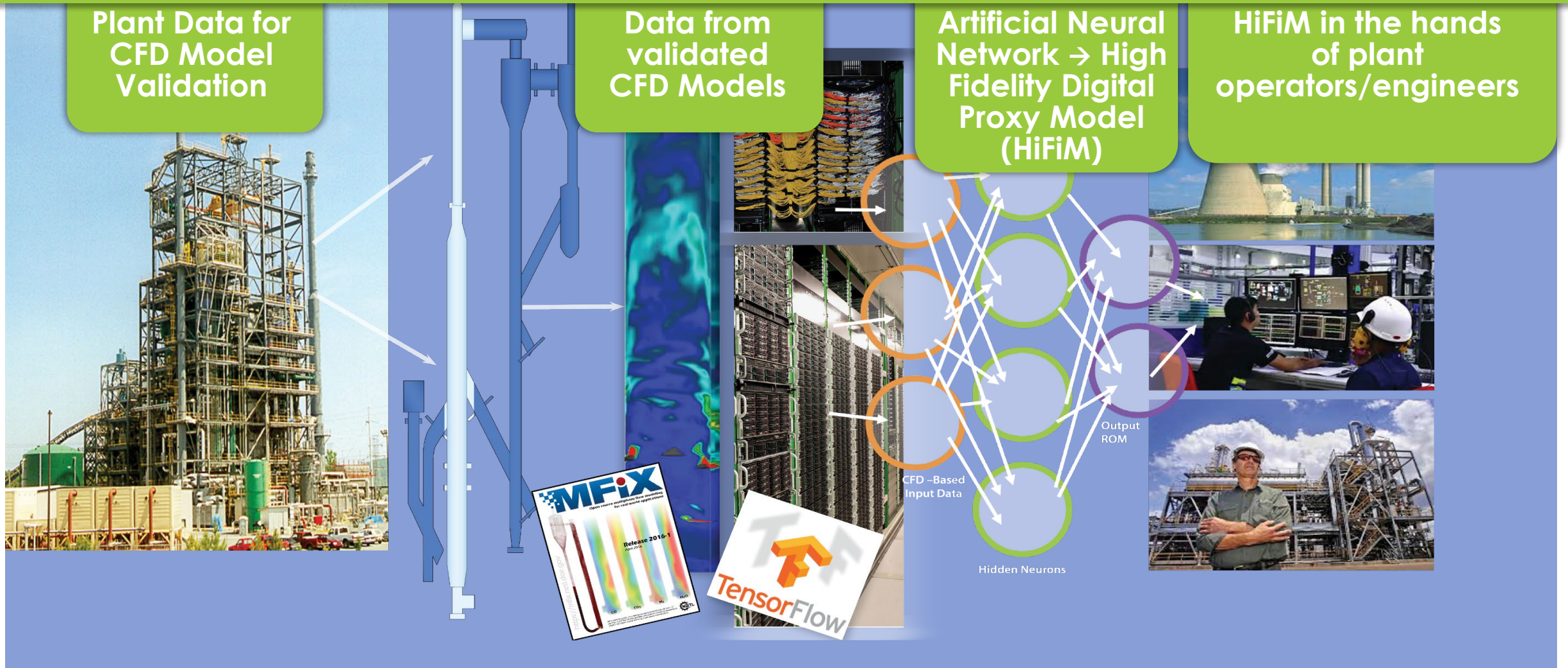
Materials Discovery



Using machine learning to enable advanced materials and tools to predict alloy behavior

Optimize Part-Load Operation of Plants

Using Computational Fluid Dynamics (CFD) and Machine Learning



CFD to HiFiM Development

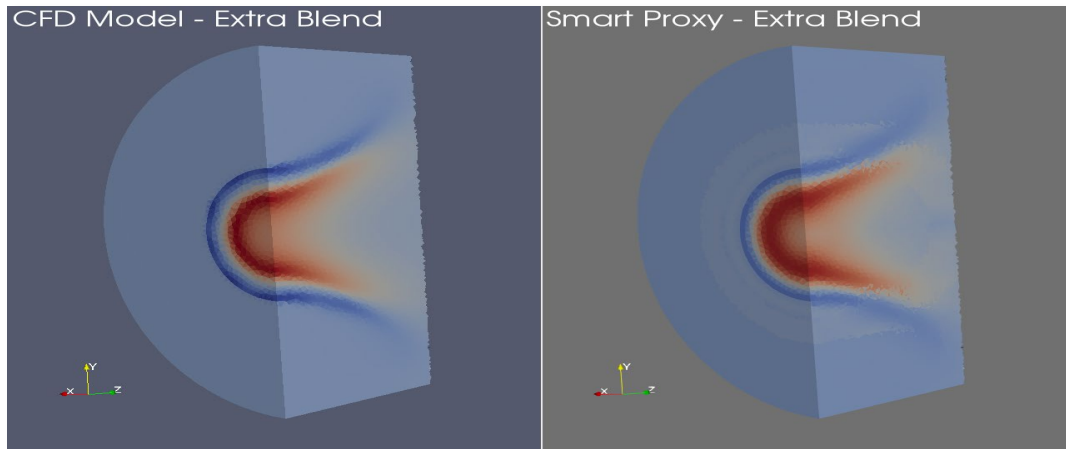
HiFiM's Using Machine Learning and Data Analytics

Transformational Technologies for Existing Plants

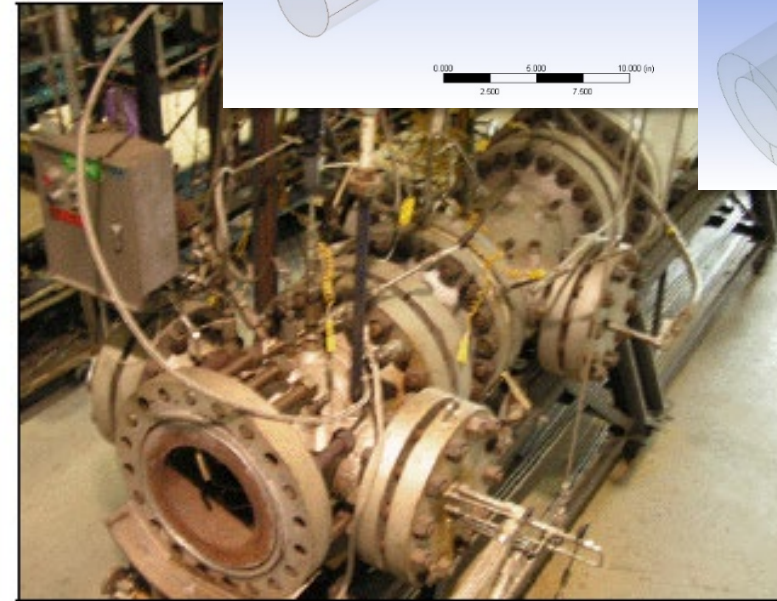
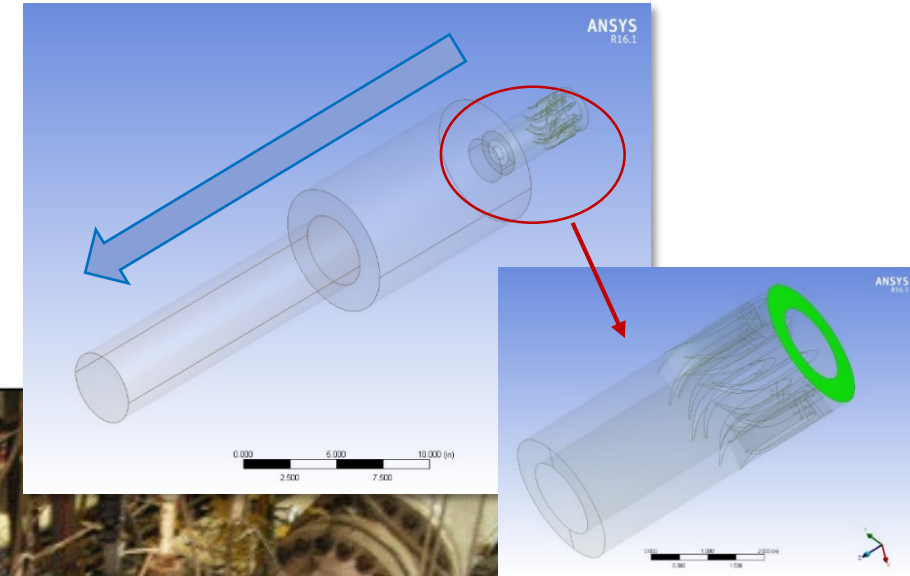
Project Objective: Apply machine learning and data analytics to develop the capability to systematically reduce detailed CFD data into a HiFiM

Project Status: NETL and WVU have successfully demonstrated the ability to produce a HiFiM from CFD data (NETL B6 combustion experiments)

Next Steps: Apply methodology to the Tri-State/Escalante 285 MW Boiler under turn-down operations.



Gas temperature of NETL's B6 combustion rig predicted by the CFD model (left) and the HiFiM (right)



NETL B6
Combustion Rig
and CFD Model

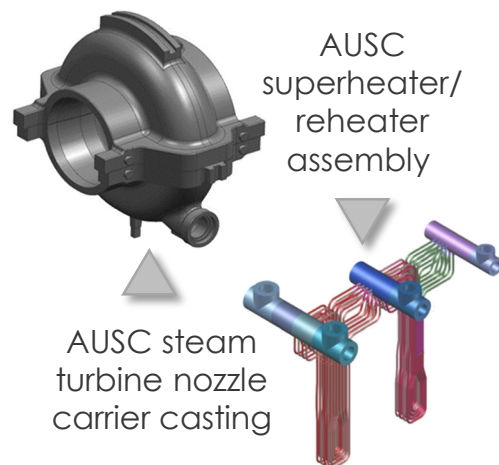


Advancing
small-scale,
modular coal
plants that are
highly efficient,
flexible, & near-
zero emissions

NETL Focus Areas

- Modular power plants
- Stable power generation
- Flexible and highly efficient operations
- Accommodate ongoing transitions from simple arrangement to complex energy systems

Advanced Ultra-supercritical (AUSC) Technology



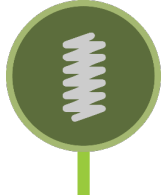



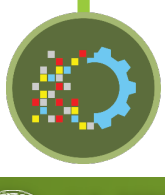
AUSC ComTest Project:

- Validating technology applicable to fossil, nuclear, and renewable power generation
- Accelerating development of domestic supply chain
- Higher efficiency and lower emissions
- Minimizing risk for building AUSC plants
- Designed world's first integrated AUSC steam turbine at 760°C

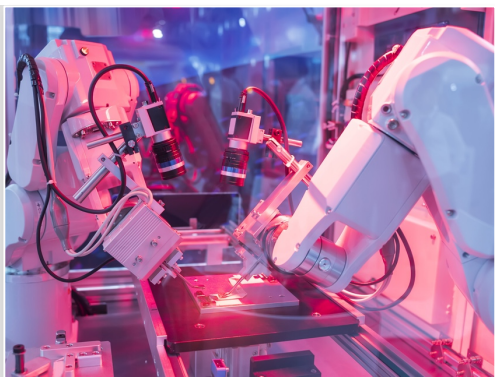
Coal FIRST Initiative

Providing secure, stable, and reliable power

The R&D under the **Coal FIRST** initiative will support future power plants

- 
- F**lexible operations to meet the needs of the grid
- 
- I**nnovative and cutting-edge components that improve efficiency and reduce emissions
- 
- R**esilient power to Americans
- 
- S**mall compared to today's conventional utility-scale coal plants
- 
- T**ransformative coal technologies designed and manufactured
- Design criteria includes:**
- High overall plant efficiency
 - Unit sizes of ~50-350 MW
 - Near-zero emissions
 - High ramp rates and minimum loads
 - Integration with thermal or other energy storage
 - Minimized water consumption
 - Reduced design, construction, and commissioning schedules from conventional norms
 - Enhanced maintenance features
 - Integration with coal upgrading, or other plant value streams
 - Capable of natural gas co-firing

Pioneering New Markets for Coal



Enhancing the value of coal as a feedstock & deriving new value-added products from coal

NETL Focus Areas

- Identify new manufacturing processes for converting coal into high-value products beyond traditional energy markets.
- Evaluate costs and technical performance of coal-based materials compared to derivatives of other feedstocks.
- Characterize the best markets for coal-based manufacturing and associated barriers.

Recovering rare earth elements from coal and coal by-product streams

- NETL is extracting rare earth elements (REEs) from the full spectrum of coal and coal-based materials.
- Supports three first-of-a-kind, domestic extraction, separation and recovery facilities.
- REEs are in the form of oxides and/or salts, which can either be directly used or converted into rare earth metals for end-use commodity.

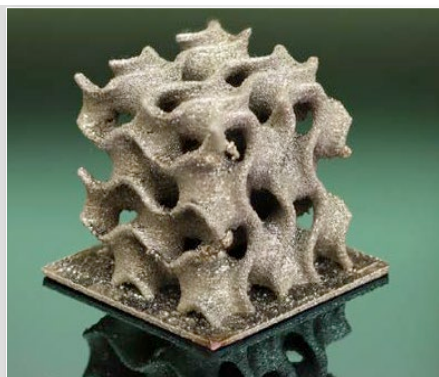


Development of Adv. REE Separations Concepts

Bench-Scale Facility for the Extraction, Separation and Recovery of REEs from Coal-Based Resources



Reducing the Cost of Carbon Capture



Developing
advanced
computational &
simulation tools, &
transformational
technologies to
reduce the cost of
CO₂ capture

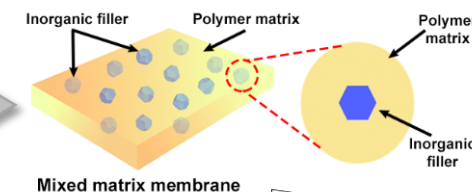
NETL Focus Areas

- Post-combustion: remove CO₂ from the combustion flue gas.
- Pre-combustion: capture CO₂ prior to combustion.
- Compression to increase the pressure and reduce the volume flow, enabling efficient transport.

Computational Tools to Rapidly Screen Novel Carbon Capture Materials

- NETL in-house researchers used high-throughput computational methodology to screen over **1 million** possible mixed matrix membranes (MMMs).
- NETL-developed polymers were found to enhance mechanical stability.
- MMMs, with NETL developed polymer, were estimated to **decrease** the cost of carbon capture from **\$63 to \$48 per metric ton** of CO₂ removed.

Predicted
properties for
over a million
possible
MMMs



Reducing Water Use in Energy Production



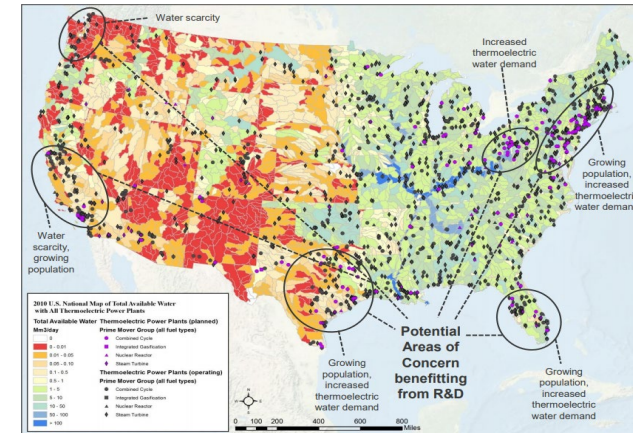
Addressing
water quality,
sustainability, &
availability for
power
generation

NETL Focus Areas

- **Increasing** water efficiency and reuse to reduce water intake and lower overall operating costs.
- **Identifying** and treating alternative sources of water to address energy-water system challenges.
- **Analyzing** energy-water system behavior to better inform decision-makers and scientists.

2018 Water Brief

- Identifies regions of water scarcity with expected growth in thermoelectric power generation.
- Recommends R&D to curb thermoelectric water use in areas of concern.
- Predicts locations that would benefit from R&D deployment.



Six potential geographic Areas of Concern that require an R&D plan are shown on a graphic of total available water (2010) overlaid with thermoelectric power generation (2018).

Evolving Topics in Oil & Gas

Enhancing Recovery



Transformational technologies to more effectively characterize and produce natural gas and oil resources

Natural Gas Utilization



Lower-cost technologies for capturing and utilizing natural gas that would be otherwise vented or flared at the field or well-pad level

Fracturing Water Reuse



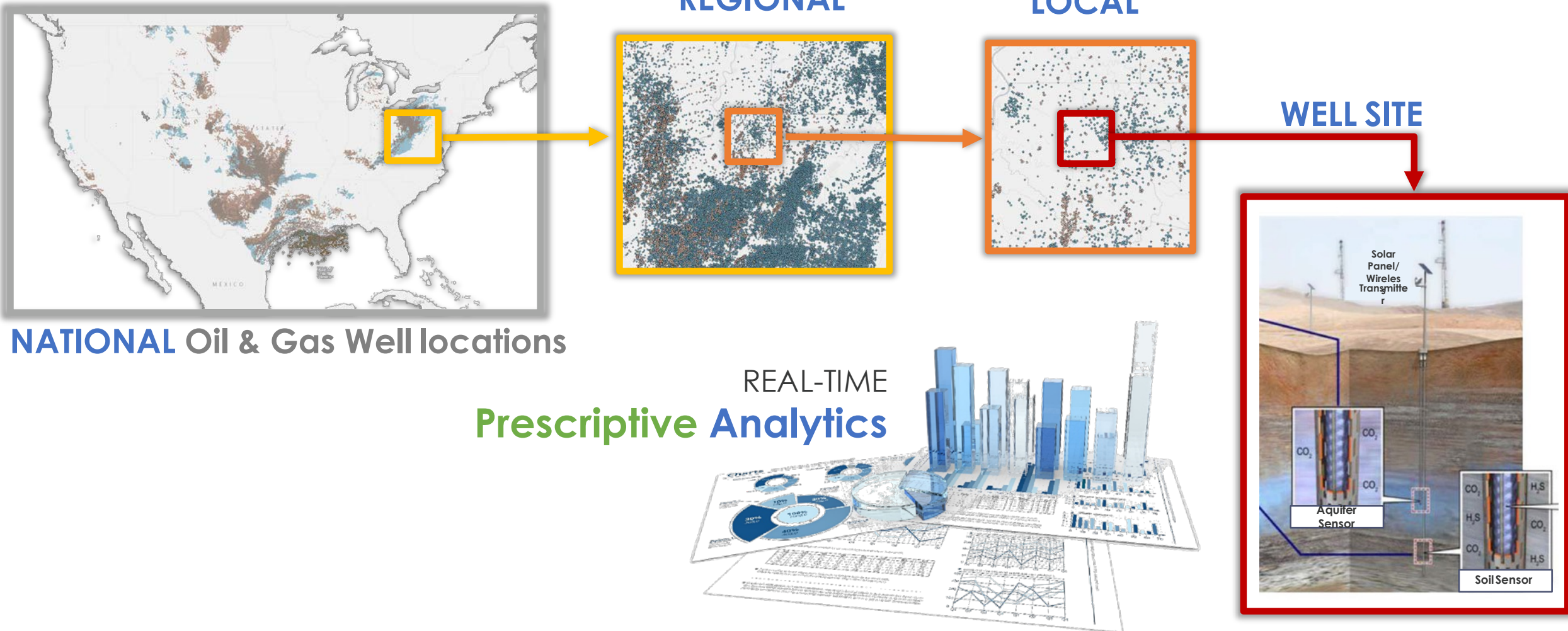
Reduce cost and improve efficiency of systems for treating fracturing flowback or produced water for beneficial reuse

Data Analytics



Addressing critical knowledge gaps in the use of data analytics and machine learning to optimize reservoir management and production operations

Real-Time Decision Science for the Subsurface



NATIONAL Oil & Gas Well locations

REGIONAL

LOCAL

WELL SITE

REAL-TIME

Prescriptive Analytics

Solar Panel/
Wireless Transmitter

CO_2
 CO_2
 CO_2
Aquifer Sensor

CO_2 H_2S
 H_2S CO_2
 CO_2 H_2S
Soil Sensor

AI Potential in the Subsurface

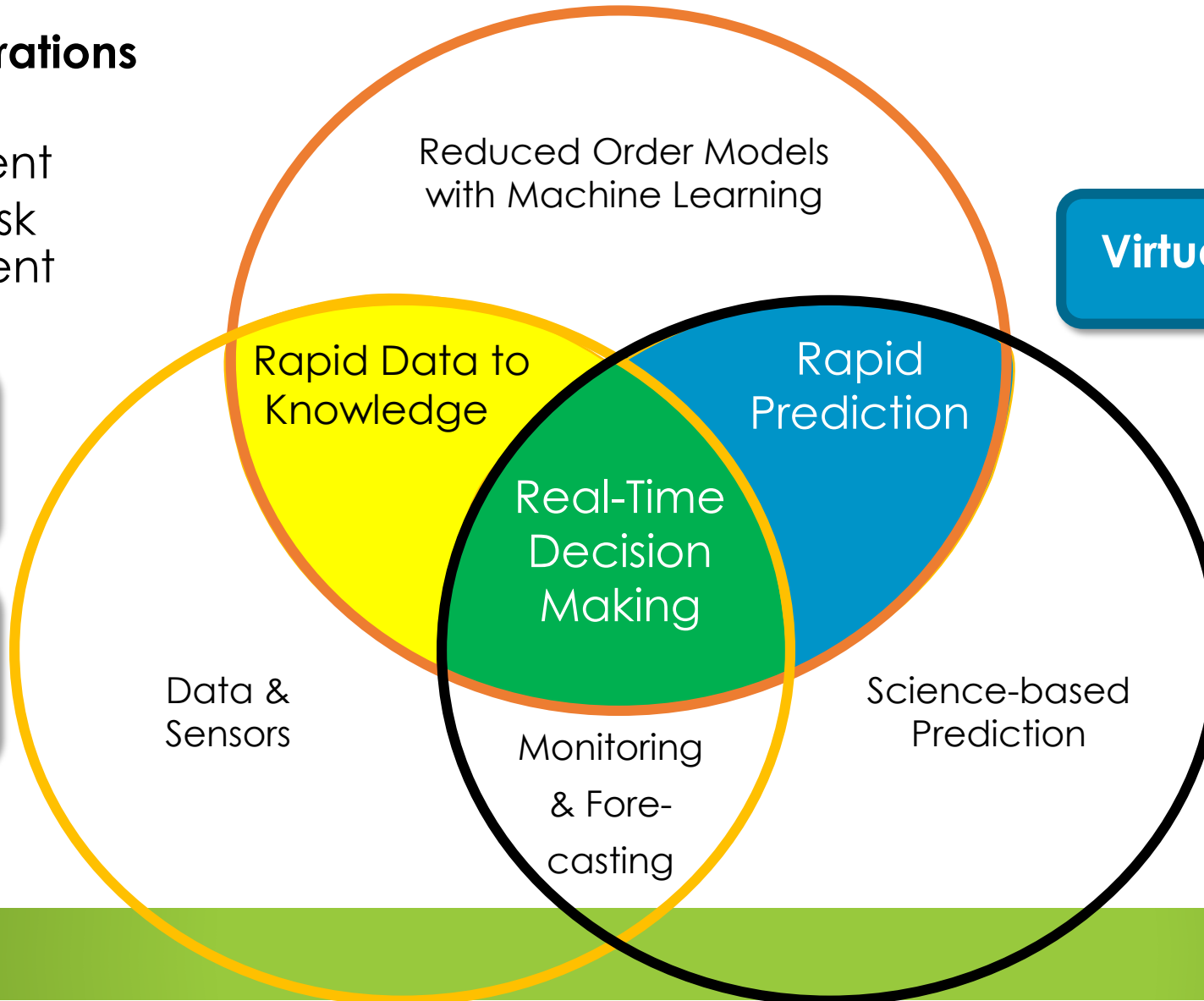
Science-based Machine Learning to Accelerate Real-Time (SMART) Decision Making

Optimized operations

- Lower cost
- More efficient
- Improved risk management

**Autonomous
Monitoring**

**Big Data
Management**



Virtual Learning

**Real-Time
Visualization**

"CT" for the Subsurface

**Real-Time
Forecasting**

"Advanced Control Room"

Data Analytics and Machine Learning at NETL Field Sites

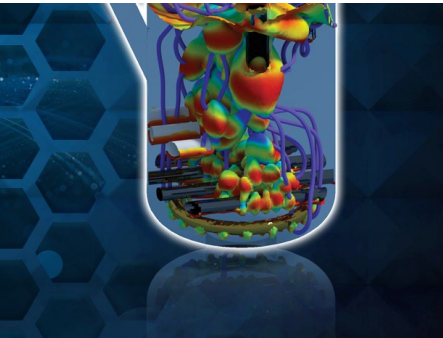
- Lessons learned from the first two MSEEL wells at the Morgantown Industrial Park site guided more extensive testing at the new well site near Core, WV.
- WVU and NNE will develop engineered stimulation designs that will be monitored using advanced fiber-optic distributed acoustic and distributed temperature technologies.
- Data generated during stimulation will provide future machine learning algorithms to be developed that can be used by all operators working in the Marcellus to develop more productive wells.



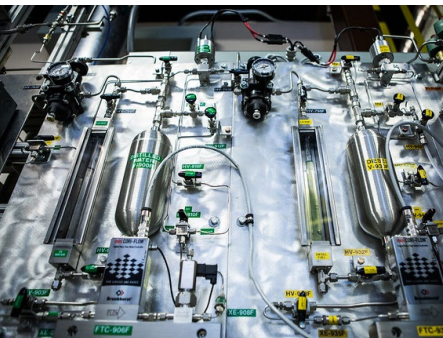
Schlumberger



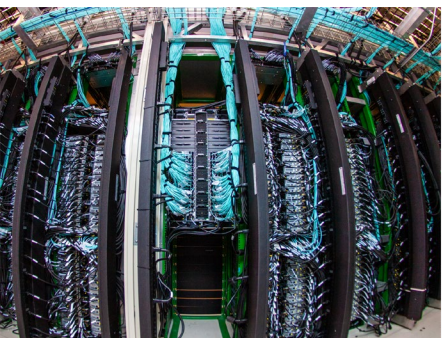
An Innovative Approach to Advanced Manufacturing



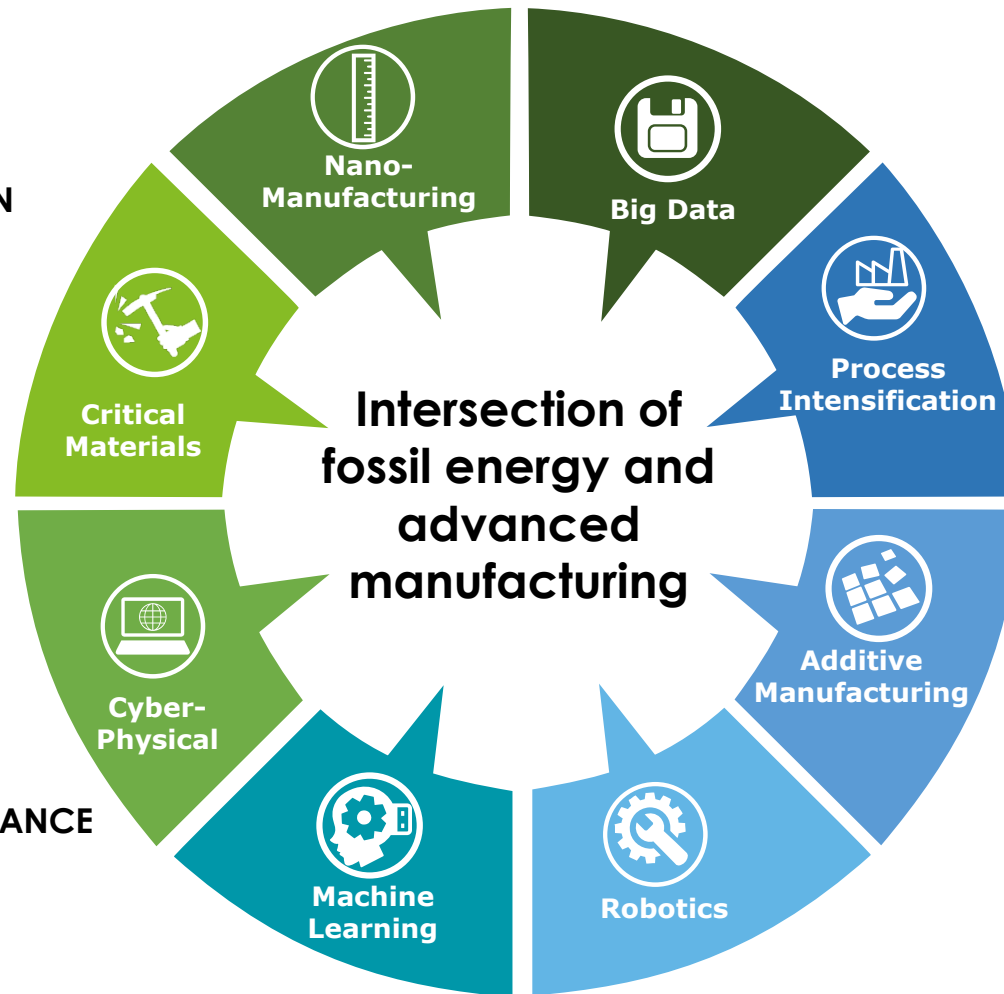
**PROCESS
INTENSIFICATION**



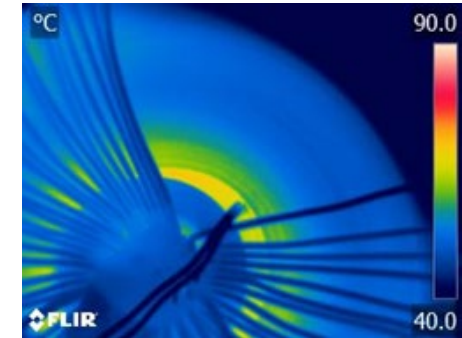
**ENERGY
CONVERSION
TECHNOLOGIES**



**HIGH PERFORMANCE
COMPUTING,
SIMULATION, &
MODELING**



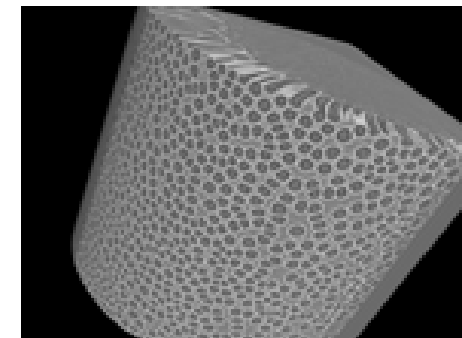
**ADVANCED POWER
ELECTRONICS**



**NEXT GENERATION
MATERIALS FOR
HARSH
ENVIRONMENTS**



**FUNCTIONAL
MATERIALS**



Advanced Manufacturing: A Regional View

The Tri-State Area's Major Organizations

Northern OH:

- The Manufacturing Advocacy and Growth Network (MAGNET)
- Ohio Manufacturing Extension Partnership
- Case Western Reserve University

Northeastern OH:

- America Makes
- Northeast Ohio Additive Manufacturing Cluster
- Youngstown Business Incubator
- Team NEO/Jobs Ohio
- Youngstown State University

Western WV:

- Robert C. Byrd Institute for Advanced Flexible Manufacturing
- Marshall University

Southwestern PA:

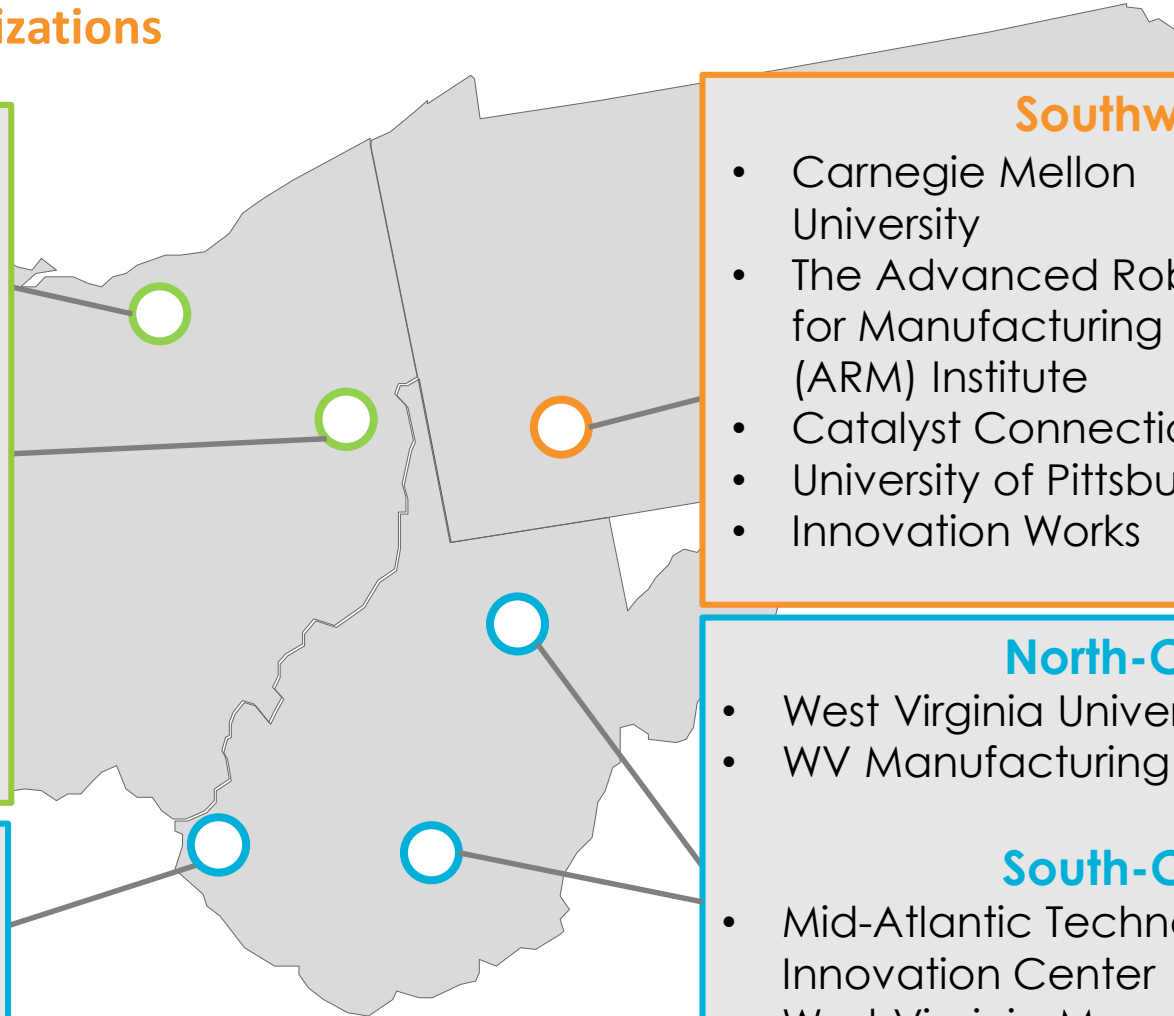
- Carnegie Mellon University
- The Advanced Robotics for Manufacturing (ARM) Institute
- Catalyst Connection
- University of Pittsburgh
- Innovation Works
- General Electric
- Alcoa
- Covestro
- Westinghouse
- Ansys
- Arconic
- ExOne
- Robert Morris University

North-Central WV:

- West Virginia University
- WV Manufacturing Extension Partnership

South-Central WV:

- Mid-Atlantic Technology, Research, and Innovation Center
- West Virginia Manufacturers Association
- TechConnect West Virginia



Accelerating Regional Advanced Manufacturing



NETL's Role

Innovate

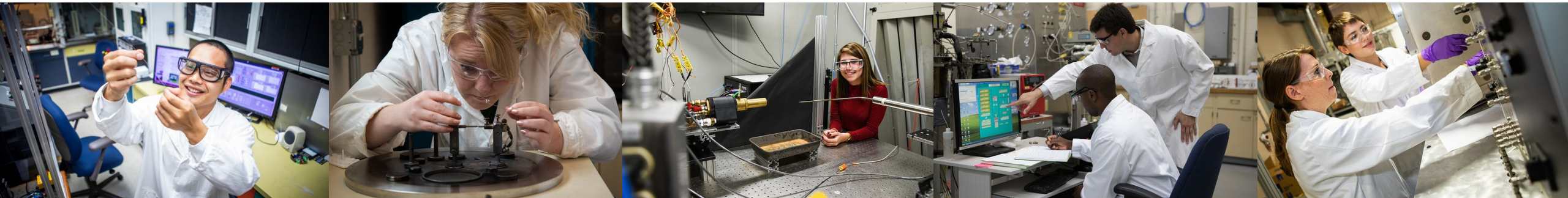
- Innovating, maturing, and deploying technologies
- Designing new standards and research procedures
- Advancing technologies to market readiness

Convene

- Bringing complementary organizations together — industry, academia, government, non-governmental organizations
- Connecting technology with workforce development needs

Implement

- Systematic decision-making techniques
- Addressing market and policy drivers
- Technology systems integration



Technology Development Pathway

An Active Portfolio from Concept to Market Readiness

COMMERCIALIZATION

Technology available
for wide-scale market use

TRL 9

DEMONSTRATION

System demonstrated
in operational environment

TRL 8

SYSTEM TESTING

System performance
confirmed at pilot-scale

TRL 6-7

DEVELOPMENT

Technology component
validated/integrated

TRL 4-5

DISCOVERY

Concept identified/proven at
laboratory-scale

TRL 1-3

TECHNOLOGY MATURATION

- ↑ Scale
- ↑ Technology Confidence
- ↑ Investment
- ↑ Private Sector Cost Share

Fundamental Studies



KNOWLEDGE-BASED DECISION MAKING

- **Systems Engineering and Integration**
 - Engineering analysis
 - Pre-FEED/FEED studies
 - NEPA
- **Decision Science and Analysis**
 - Screening studies
 - Techno-economic analysis
 - Technology Readiness Assessments

Established & Expanding Partnerships

An Active Portfolio from Concept to Market Readiness



FE has **over 600 partnerships with industry, academia and other government organizations** and funds **900+ R&D projects** nationwide.



How to work with NETL



The TOOLBOX



- Cooperative Research and Development Agreement (CRADA)
- Contributed Funds-In Agreement (CFA)
- Memorandums of Understanding (MOU)/
Memorandums of Agreement (MOA)
- 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 IP 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 FedBizOpps.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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 @NationalEnergyTechnologyLaboratory



U.S. DEPARTMENT OF
ENERGY