Big Data and Machine Learning in NETL's Fossil Energy Portfolio

NATIONAL ENERGY TECHNOLOGY LABORATORY

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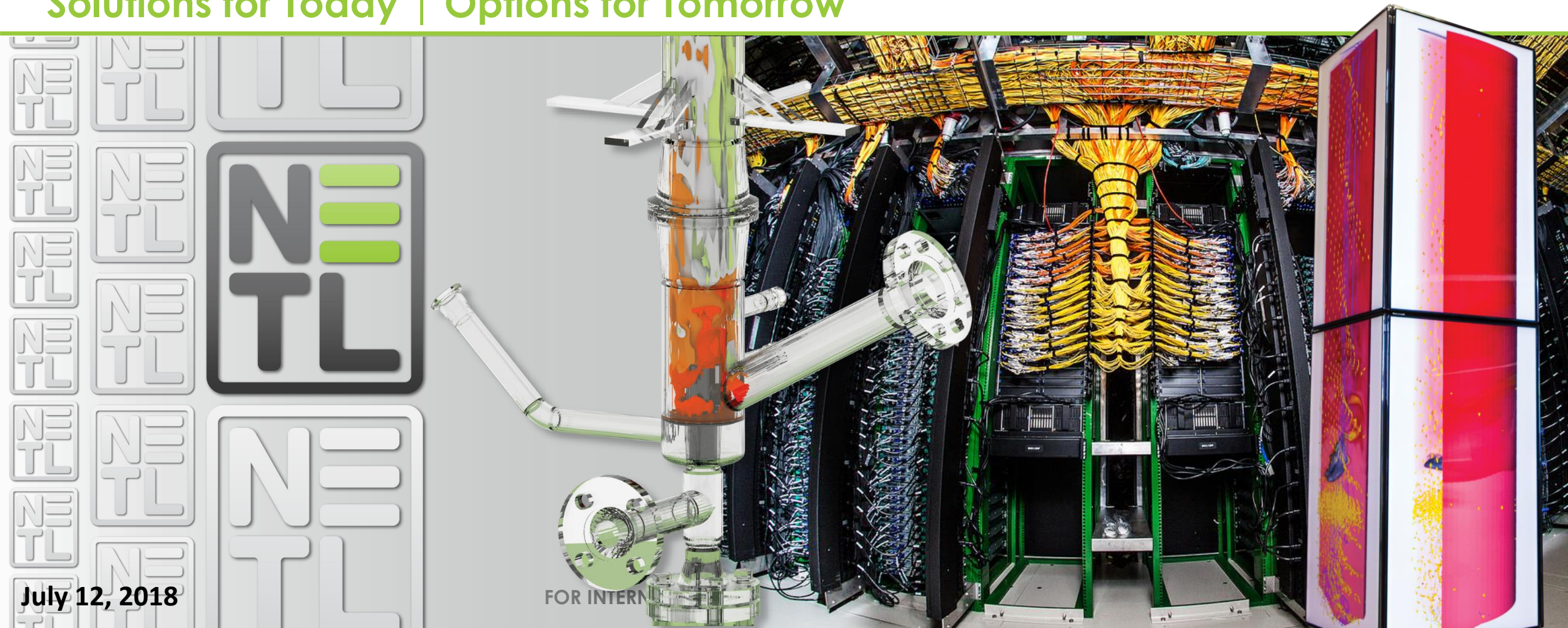
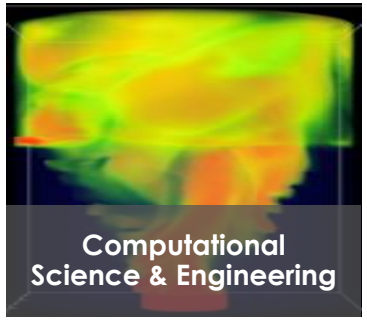
Chief Research Officer

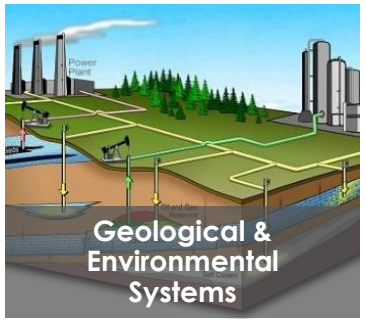
Solutions for Today | Options for Tomorrow



July 12, 2018

Core Competencies & FE Technology Thrusts





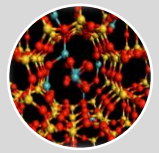
Carbon Storage

Carbon Capture

Sensors & Controls

Advanced Materials

Advanced Computing



Advanced Energy Systems

Water Management

Rare Earth Elements

Enhanced Resource Production

Environmentally Prudent Development

Methane Hydrates

Offshore

Natural Gas Infrastructure

Unconventional

Support to Other DOE Offices

Energy Efficiency & Renewable Energy (EERE)

Vehicles

Solid State Lighting

Geothermal

Electricity Delivery & Energy Reliability (OE)

Microgrid

Energy Storage

Energy Security & Restoration

FE Technology Thrust Integration


Advanced Energy Systems


Carbon Storage

Rare Earth Elements


Carbon Capture


STEP (Supercritical CO_2)


Crosscutting Research & Analysis

COAL PROGRAM

COAL INITIATIVES

Revitalize and Extend Coal

- Modernize existing coal plants
- Get the Most out of Coal Resources
- Enable CO2 as a Commodity for Energy Security
- Develop & Deploy Next Gen Coal-Based Energy Systems

Impact

- Manufacturing Revitalization
- Global Competitiveness
- Energy Dominance
- Economic Growth

OIL & GAS PROGRAM

OIL & GAS INITIATIVES

Grow Oil & Gas

- Improved Recovery Efficiency of Resources
- Natural Gas Infrastructure Improvement
- Advanced Resource Characterization
- Natural Gas Utilization Development
- Reduced Operational Impacts


Methane Hydrates

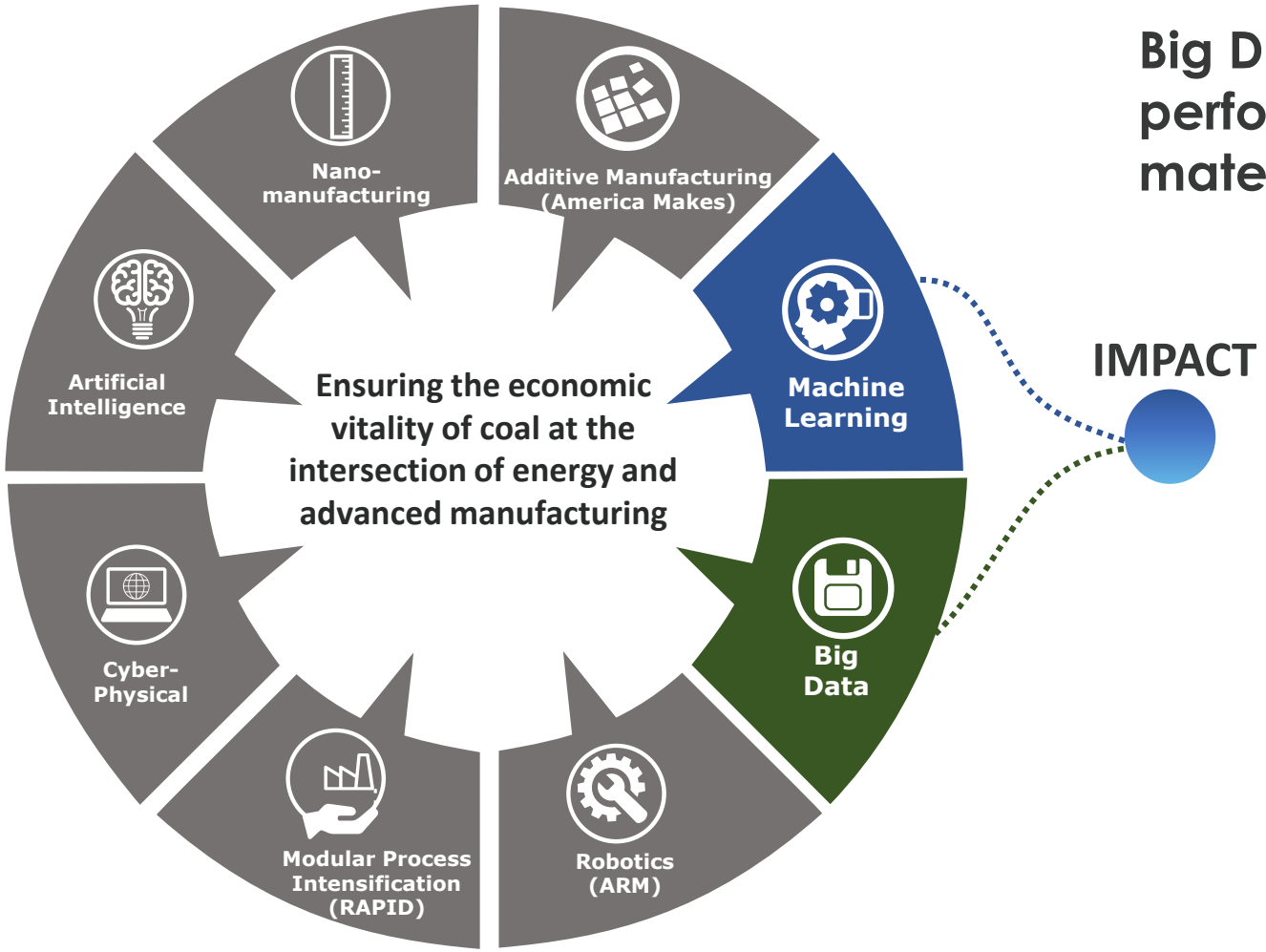

Methane Quantification


Unconventional Oil & Gas


Midstream Infrastructure


Offshore

Fossil-focus in Advanced Manufacturing



Big Data and Machine Learning to improve the performance and economics of energy and materials systems

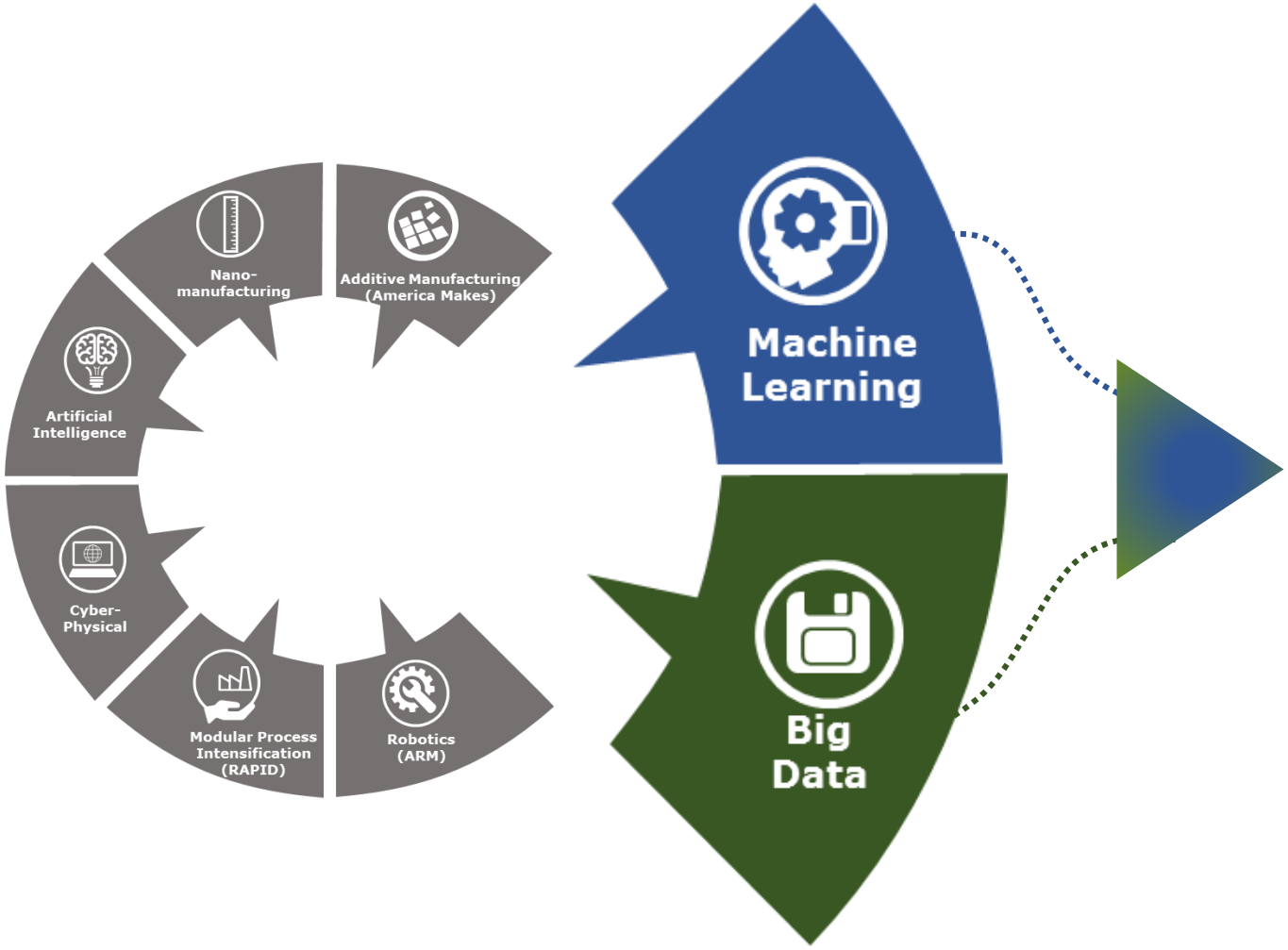
The advanced coal energy systems of the future:
Create new long-term pathways for advanced coal energy (ACE) systems, supported by the most advanced and innovative technologies;

A competitive, resilient and flexible fleet:
Identify ways to strengthen and utilize existing plants that would provide affordable near-term energy security benefits and also support future power and infrastructure needs amidst a changing energy landscape; and

New Markets:
Develop new products and uses of coal and coal by-products to create new businesses and industries.

NETL collaborates in three of the Manufacturing USA Institutes: America Makes, RAPID, and ARM.

Active Portfolio Leveraging Big Data and Machine Learning



- Predictive Maintenance
- Digital Twinning
- Sensors and Controls
- IDAES
- CCSI2
- HPC4CM
- Subsurface

Predictive Maintenance

Key Outcomes

Utilizing data from distributed sensors and applying machine learning to diagnose faults before they occur will lead to:

- Converting from a culture of preventative maintenance to one of condition-based maintenance.
- Identifying operational discontinuities and informing decisions on operational efficiency
- Enabling plants to operate in an environment where they are required to cycle more frequently than originally envisioned

Predictive Maintenance at NETL

- Microbeam Technologies, Inc.

  Integrated Predictive Maintenance to integrate the operations of the tool into plant control systems and plant operating parameters. These improvements will potentially allow automation of coal selection and blending and will enhance the efficiency and long-term reliability of coal plants.

- SparkCognition

  The approach utilizes existing sensor and operational data being collected at coal-fired power plants and apply its machine-learning algorithms to detect and diagnose premature equipment failure. Benefits from successful completion of this project include optimizing the sensor inputs needed for fault detection, understanding the impacts of control decisions due to flexible operations, and extending the life of critical equipment.

Digital Twinning

Key Outcomes

Compliments machine learning by developing a twin computational model to understand and predict the impact of change to the real world application:

- Cost savings
- Risk mitigation
- Safety and security improvements

Digital Twinning at NETL

- JOULE coal plant digital twins
  Utilize coal plant data to produce Digital Twin models including all necessary aspects of the physical asset or larger system such as thermal, mechanical, electrical, chemical, fluid dynamic, material, lifing, economic and statistical. These models also accurately represent the plant or fleet under a large number of variations related to operation — fuel mix, ambient temperature, air quality, moisture, load, weather forecast models, and market pricing.

Big Data

Prescriptive Analytics

Sensors and Controls

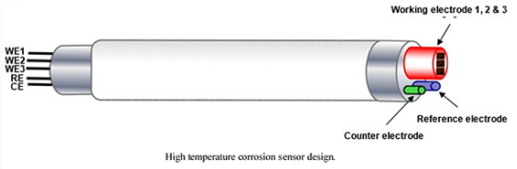
Key Outcomes

Advancing sensors and controls with material improvements, algorithm development, data-driven hybrid models integrated into the central controls, and application of advanced control systems (including distributed intelligence):

- Increase coal plant efficiency
- Reduce forced outages
- Safety and security improvements

Sensors and Controls at NETL

- Real-time measurement of temperature profiles in boiler different combustion zones
- Detection of target gases at high temperatures and electrochemical sensors
- Wireless Condition-Based Monitoring
- Distributed Fiber Optic Sensing Systems



High temperature corrosion sensor design.

Institute for the Design of Advanced Energy Systems (IDAES)

Key Outcomes

The Institute is a resource for the development and analysis of innovative advanced energy systems via process systems engineering tools and approaches. IDAES benefits are:

- Process Synthesis, Integration, and Intensification
- Process Control and Dynamics
- Apply to development of novel energy systems
- Transformational Carbon Capture
- National Lab and University Capability
- Open Source

IDAES at NETL

- Institute for the Design of Advanced Energy Systems (IDAES)
  IDAES team has implemented a modular framework and model library that supports large-scale optimization of advanced energy systems; applied machine learning-based parameter estimation tools; developed a roadmap to support the existing fleet of coal-fired power plants; and established an industry stakeholder advisory board.

IDAES
Institute for the Design of Advanced Energy Systems

Rational Design for Solvents and for carbon capture experiments (CCSI2)

Key Outcomes

The Carbon Capture Simulation Initiative (CCSI) is a partnership among national laboratories, industry, and academic institutions that is developing and deploying state-of-the-art computational modeling and simulation tools to accelerate the commercialization of carbon capture technologies. CCSI2 Toolkit benefits are:

- Prediction of coal quality in operations
- Carbon capture modeling
- Advanced process simulation

CCSI2 at NETL

- CCSI2
  The CCSI Toolset is designed provide end users in industry with a comprehensive, integrated suite of scientifically validated models, with uncertainty quantification, optimization, risk analysis and decision making capabilities. The CCSI Toolset incorporates commercial and open-source software currently in use by industry and is also developing new software tools as necessary to fill technology gaps identified during execution of the project. The current focus is on using machine learning and data from past pilot projects to optimally design experiments for carbon capture

High Performance Materials Development (HPC4M)

Key Outcomes

Through the high performance computing for manufacturing (HPC4M) program, key challenges in developing, modifying and qualifying new materials are being advanced using machine learning and big data:

- Accelerates new material identification
- Advanced material properties

HPC4CM at NETL

- HPC4CM
  NETL is focused on improving the existing coal fleet by characterizing, producing, and certifying high performance materials for use in extreme environments. To do this, NETL focuses on four areas of research in materials: computational materials design, advanced structural materials, functional materials for process performance, and advanced manufacturing techniques.

Subsurface

Key Outcomes

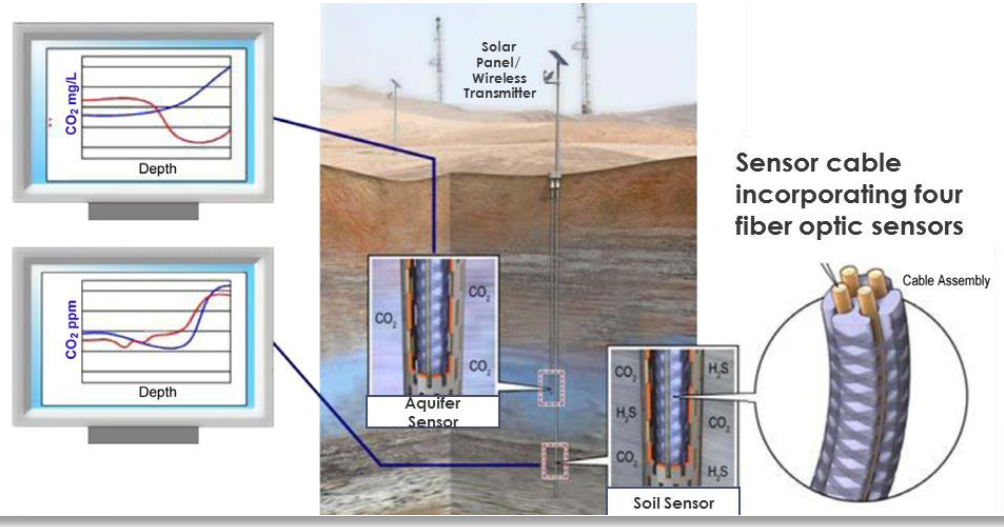
Research, scientific, and engineering data resource are increasingly available online. For the subsurface, these resources span a tremendous amount of data, models and analysis. Energy Data eXchange (EDX), helps improve access to these resources by:

- Accelerates coordination and access
- Advanced search capabilities
- Potential for big data and machine learning

Subsurface at NETL

- Subsurface

  Successfully engineering the subsurface requires advanced quantitative assessment and characterization of the geologic strata, tools, and materials used to access and image the deep subsurface, as well as computational tools required to analyze significant volumes of data and model complex coupled reactions.



What's Next?

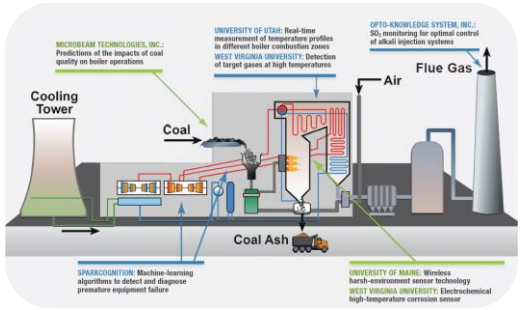
NATIONAL ENERGY TECHNOLOGY LABORATORY

MACHINE LEARNING FOR PROGRAM MANAGEMENT

- Improvements in program management and stewardship through machine intelligence
- Creating a more robust portfolio and ensuring program success

SENSORS AND CONTROLS

- Using smart manufacturing to bring down costs
- Leverage integrated sensors and control systems to increase plant efficiency, understand component health, and improve environmental performance

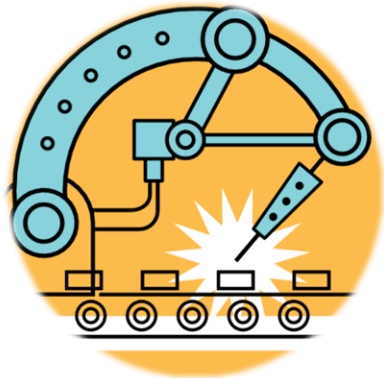


POWERPLANT AUTOMATION

- Cutting edge research projects aim to reduce operating and maintenance costs to make powerplants economically competitive
- Example project includes development of large-diameter, multi-nozzle turbine combustors

ROBOTICS ENABLED TECHNOLOGIES

- Robotic technology to enable automatic plant inspection and repairs
- Robotic technologies provide non-destructive testing inspections ready for commercial applications



BLOCKCHAIN & CYBERSECURITY

- Develop that enhance the cybersecurity of advanced sensor and control networks
- Enhance plant flexibility with secure sensor data transmission

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U.S. DEPARTMENT OF ENERGY

Thank You.