



BLAZE

BURNER LABORATORIES TO ADVANCE FUEL
UTILIZATION FOR THERMAL ENERGY



U.S. DEPARTMENT
of ENERGY



Today's Presentation



BURNER LABORATORIES TO ADVANCE FUEL
UTILIZATION FOR THERMAL ENERGY



Meet the BLAZE Team



BLAZE Assets



Testbeds



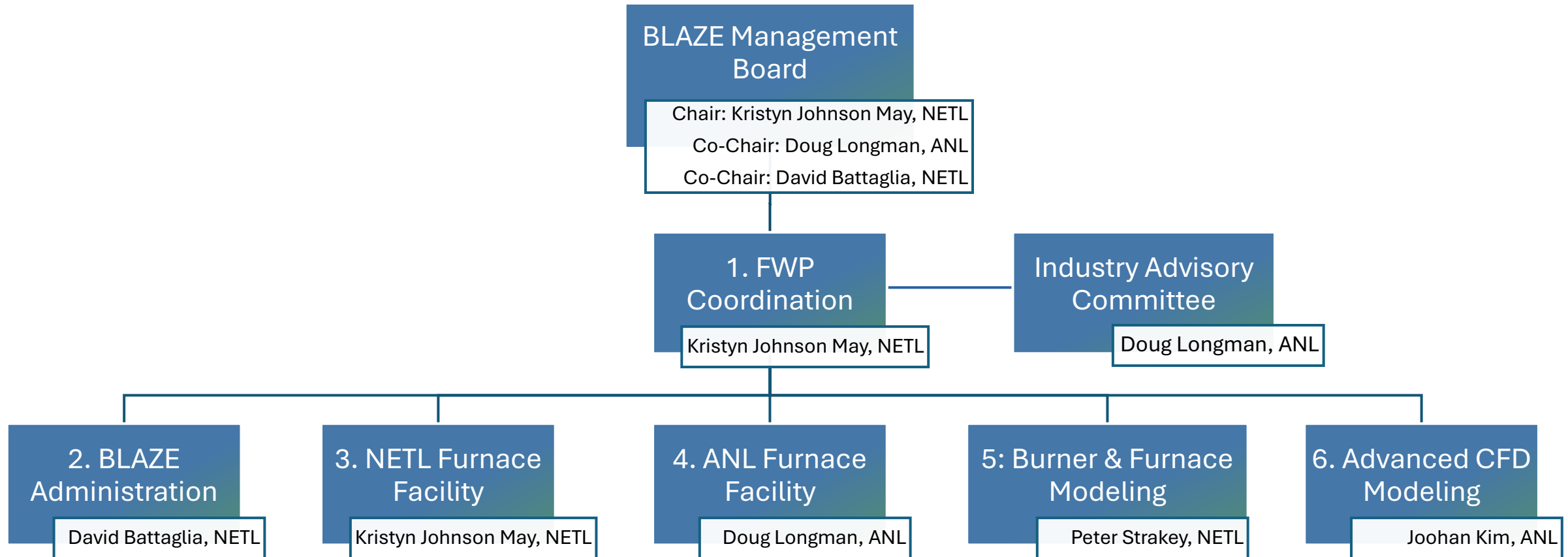
Technology Development



U.S. DEPARTMENT
of ENERGY



BLAZE Org Chart



Meet the BLAZE Team



Kristyn Johnson May, Ph.D.
BLAZE PI
Research General Engineer
Power, Fuels & Chemicals
Oil & Gas CoE



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GTI PI
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Research Scientist
Multi-Physics Applications
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Clint Bedick, Ph.D.
Research General Engineer
Power, Fuels & Chemicals



Peter Strakey, Ph.D.
Research General Engineer
Power, Fuels & Chemicals

NETL Overview

NETL:

- One of three energy technology national labs
- The only DOE government-owned and operated (GOGO) national lab
- Part of DOE's Hydrocarbons and Geothermal Energy Office



Multiple R&D Sites
Operating as One Lab



Three primary components:

1. Applied Research & Development
2. DOE Program Execution
3. Industry Partnerships through Centers of Excellence



OIL & GAS
CENTER *of* EXCELLENCE

Enable secure, efficient, and low-impact oil and gas systems through integrated research aligned with DOE priorities and industrial needs.

ANL Overview

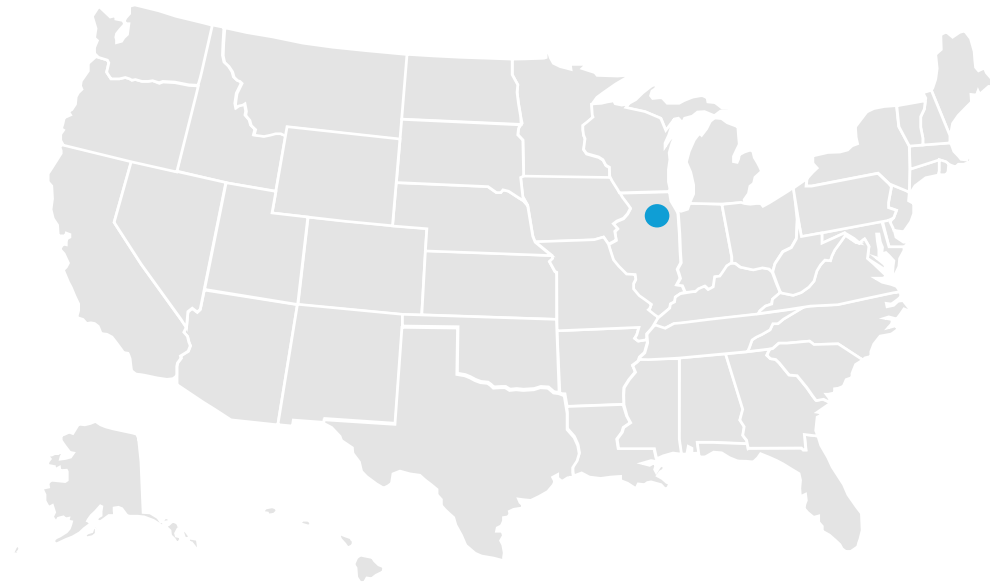


ANL:

- The First National Lab
- Government owned, contractor operated (GOCO)
 - UChicago LLC operates for DOE Office of Science
 - Multi-disciplined Laboratory
- 21 divisions
- 6 national scientific user facilities

Department of Advanced Propulsion and Power

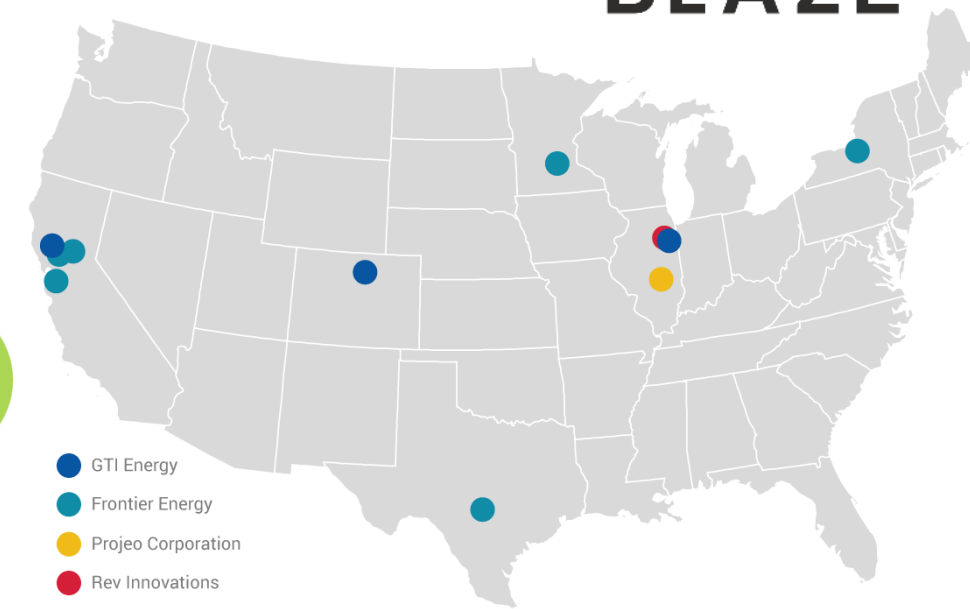
- Mobile & stationary applied combustion research
- Unique Diagnostics
- High-Fidelity Simulations



GTI Energy Overview

GTI Energy:

- Non-profit R&D company
- 80+ years of experience and leadership in energy production, storage, delivery, and use
- 175+ Active industry and government partnerships
- 10+ Industry collaboratives



Heat & Power R&D:

- 300+ active projects
- 7 laboratories, including industrial and hydrogen combustion labs
- 30+ projects on hydrogen R&D and pilots in the last six years



Funding Overview



HGEO Investment

DOE HGEO has funded a facility to develop an industrial furnace to serve as a single burner testbed.

That furnace and supporting infrastructure is currently being installed for 2026 operation.



ITO Award

DOE ITO has awarded \$10M to expand BLAZE for Capabilities for Advanced Fuel Combustion Technologies

This investment will establish additional state-of-the art testbeds, computational modeling, and auxiliary services.



Cost Share

Over 20 Letters of Commitment

\$2 Million in Cost share

Invaluable insights and future commitment to serve on the Advisory Committee

BLAZE Overview



BURNER LABORATORIES TO ADVANCE FUEL UTILIZATION FOR THERMAL ENERGY



BLAZE Vision

- **Accelerate the development of innovative combustion systems**
- Enable U.S. industry to employ adaptable heating solutions that strengthen their operations
- Reduced fuel costs through improved efficiency
- Bolstered stability from using varying fuel supplies



BLAZE Mission

- **Establish and operate cutting-edge, industry-accessible testbed facilities**
- Dedicated to advancing the commercial adoption of fuel-flexible combustion technologies
- Leverage unique national laboratory expertise and facilities of the National Energy Technology Laboratory and Argonne National Laboratory



Strategy

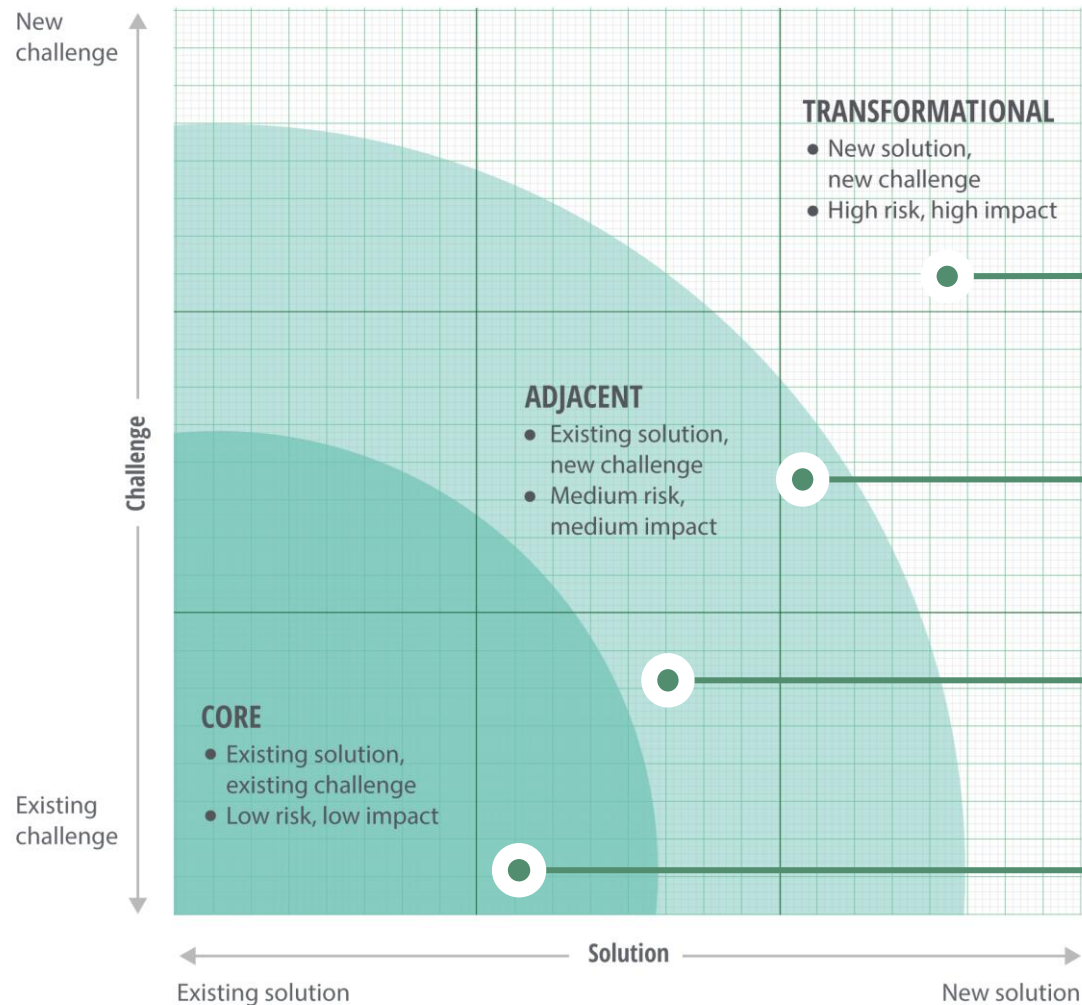
- **Advance burner technology, multi-burner flame interactions, safety, sensors, and materials testing**
- Rigorously evaluate specialized process design and equipment for large-scale use of advanced fuels
- Multiple industrially relevant furnace and boiler configurations
- Develop complementary models leveraged for scale-up and adoption



Goals & Objectives

- **Bolster stability for U.S. industry by enabling the use of varying fuel supplies**
- Advance commercial adoption of fuel-flexible combustion technologies
- Ensure safe adoption of new combustion technologies via safety and sensor accommodation
- Reduce fuel costs for U.S. industry through improved efficiency

Innovation Matrix – Burner Example



ALTERNATIVE FEEDSTOCK to NEW PRODUCT

Creating new fuel-flexible burner technology, that is competitive in a global fuels market

ALTERNATIVE FEEDSTOCK to EXISTING PRODUCT

Validating existing burner technology for new fuel blends dictated by geography-driven supply chains and regulation

CURRENT FEEDSTOCK to NEW PRODUCT

Developing new burner technology via CFD and AI-ML optimization

CURRENT FEEDSTOCK to EXISTING PRODUCT

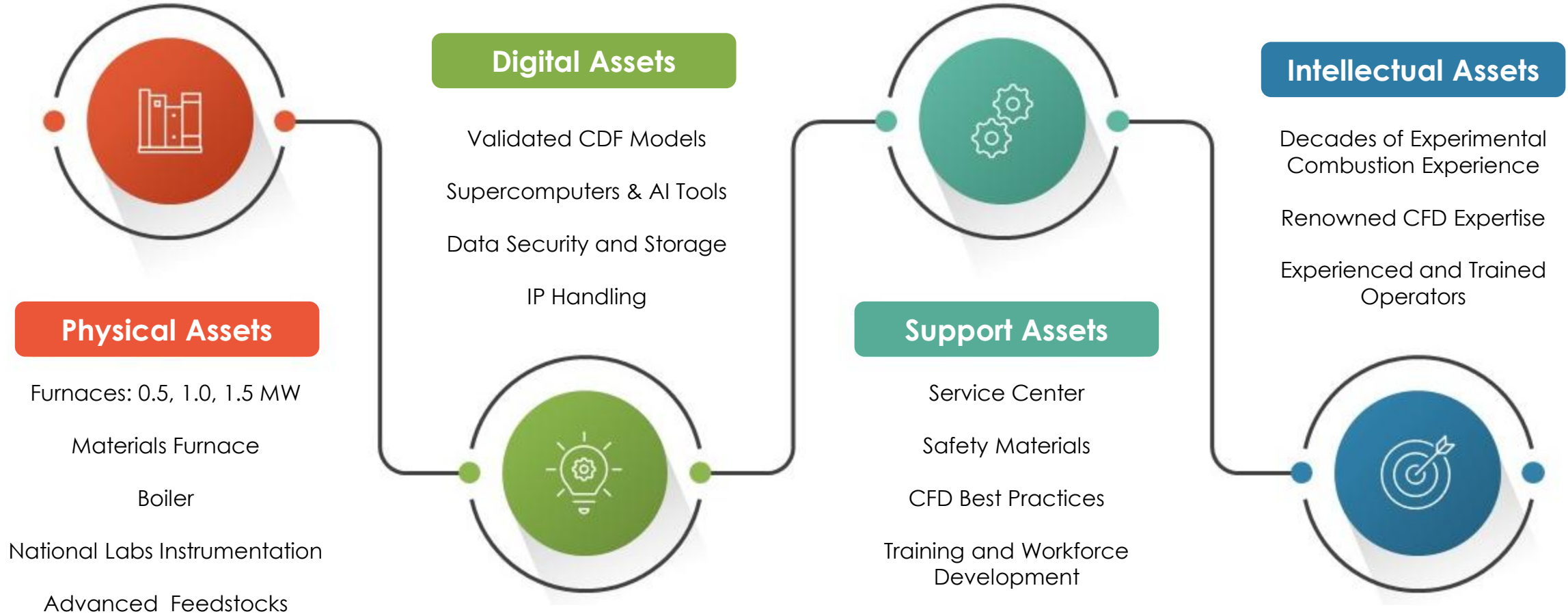
Improving existing burner design for user-specific needs, improved efficiency, or reduced NOx emissions

Source: Harvard Business Review.¹⁵

Deloitte Insights | deloitte.com/insights

BLAZE Assets

A sophisticated platform for Test-as-a-Service (TaaS) or Collaborative Research



Today's Agenda



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BLAZE Assets



Testbeds



Technology Development

BLAZE Physical Assets



Direct Fired - Single Burner
1.7 MMBTU/hr



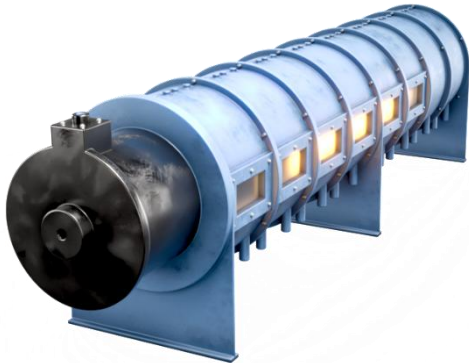
Direct Fired - Multi-burner
3.4 MMBTU/hr



Indirect Firing
5 MMBTU/hr



Boiler Simulators
8, 12, 16 MMBTU/hr



National Labs
Instrumentation

Flame and Wall
Imaging

Emissions
Global and Local

Temperature
and Heat Flux

Safety Flashback
and Leak Detection

Real-time
Monitoring

Advanced Feedstock
Blends

Natural Gas

Hydrogen

Biogas Simulant

Preheated Air

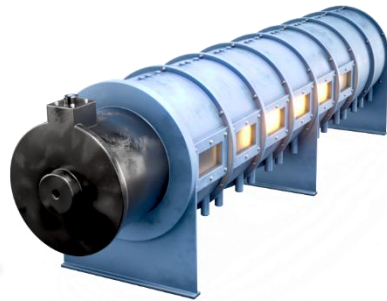
Readied and
Permitted

BLAZE Physical Assets



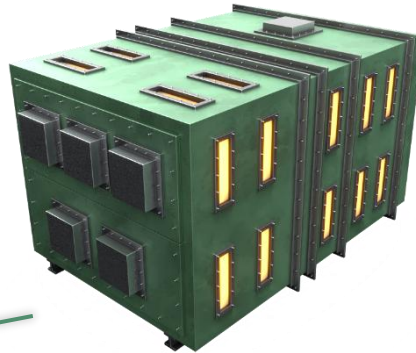
Indirect burners and indirect firing

Feedstocks: NG – H₂ – Air
5 MMBTU/hr (1.5 MW)



Boiler Simulators

Feedstocks: NG – H₂ – Preheat Air
8, 12, 16 MMBTU/hr



Direct firing, multi-burner interaction

Feedstocks: NG – H₂ – Biogas – Preheat Air
3.4 MMBTU/hr (1 MW)



Direct firing, single burner

Feedstocks: NG – H₂ – Biogas – Preheat Air
1.7 MMBTU/hr (500 kW)

State-of-the-art Diagnostics

Wall temperatures
Flame temperature uniformity
Time-varying pressure & acoustics
Non-destructive materials testing
Flame presence and position
NO_x emissions along the flame
NO_x global emissions



Illinois

West Virginia

BLAZE Digital Assets

Key Computational Skills and Facilities to support Industry



Supercomputing Power & AI/ML

- **Among the fastest worldwide:** Aurora exascale computer and Joule 3 Supercomputer
- **Explore problems:** WATT is designed for machine learning, artificial intelligence, data mining, and data analytics
- **Trustworthy AI/ML solutions** SAMI is positioned to accelerate applied technology development

Validated CFD Models

- **Alternative Fuel Chemical Kinetics:** furnaces and boilers modeled and validated on advanced feedstock combustion, providing **CFD best practices guidance**
- **Scale-up:** High-fidelity experimental data across multiple testbeds **underpin physics and validate model** performance for user hardware

Data Security & IP Handling

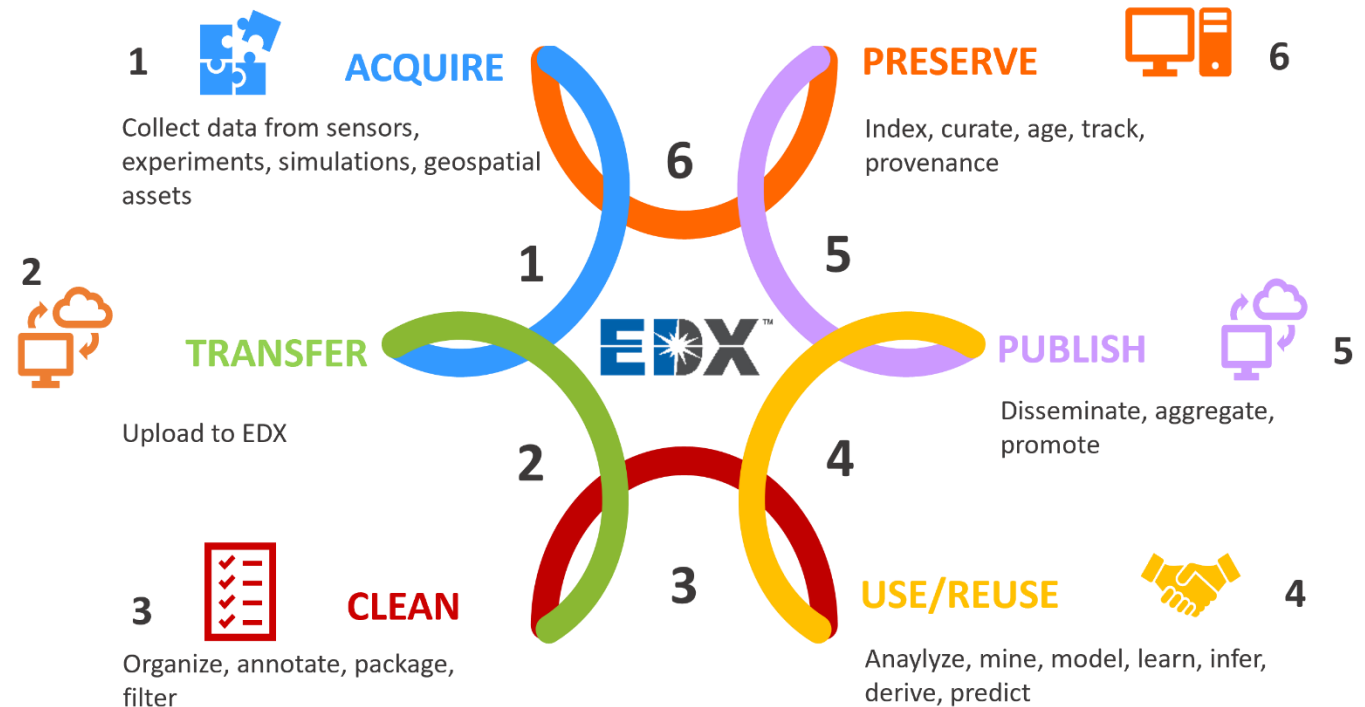
- **Data Storage and Security:** EDX is a secure environment for multi-organizational research teams to share, build, and collaborate
- **IP Handling:** bring IP into the center without losing confidentiality and generate IP by using the center



BLAZE Data Security

Energy Data Exchange (EDX) for Secure Data & IP Handling

- **Data Storage and Security:** EDX is a secure environment for multi-organizational research teams to share, build, and collaborate
- **IP Handling:** bring IP into the center without losing confidentiality and generate IP by using the center
- Restricted access to registered users
- Private workspaces have additional registration requirements, use role-based security, and meet federal security standards
- Adherence to DOE Cyber policies and protocols



BLAZE Support Assets

Supporting the Customer Journey via the Service Center



Foundational Service Center Support

Training and Workforce Development

Leveraging partnerships with ORNL, the ITO Better Plants program, ISEED, and the Catalyst Connection project

Safety Trainings

Providing access to premier safety protocols and best practices for handling hydrogen and other extreme gas environments

Webinars and Reports

BLAZE continuously contributes new webinars and reports specifically on hydrogen-related materials, industrial combustion, and integration

BLAZE Intellectual Assets

Combustion Expertise

Decades of Renowned Expertise:

Experimental and computational subject matter experts to de-risk the exploration of fuel-flexible technologies

Equipped Operators

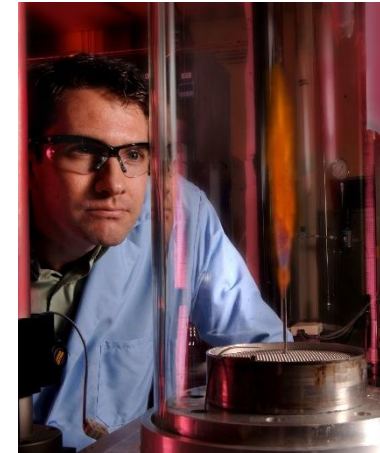
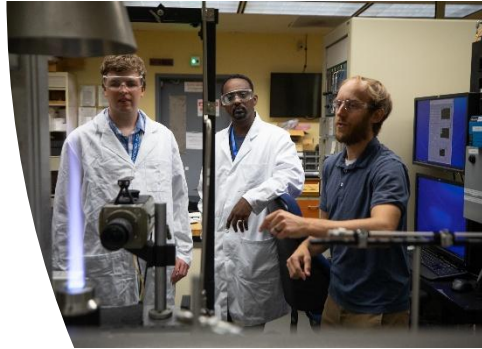
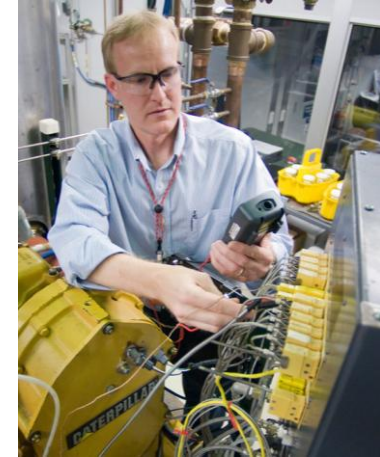
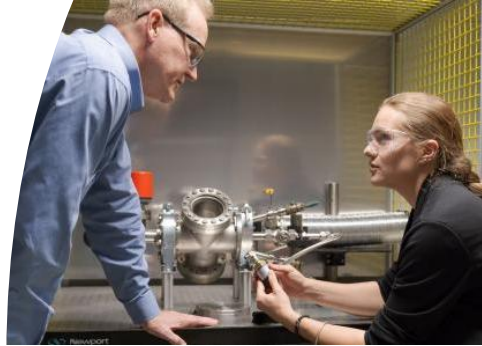
Skilled and Certified:

Technicians and machinists ready to install, test and modify equipment, with advanced fuels experience

Robust ES&H Systems

ISO and OHSAS Standards:

Ensuring protection of the public, employees, the environment, facilities, and operations



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BLAZE Assets



Testbeds



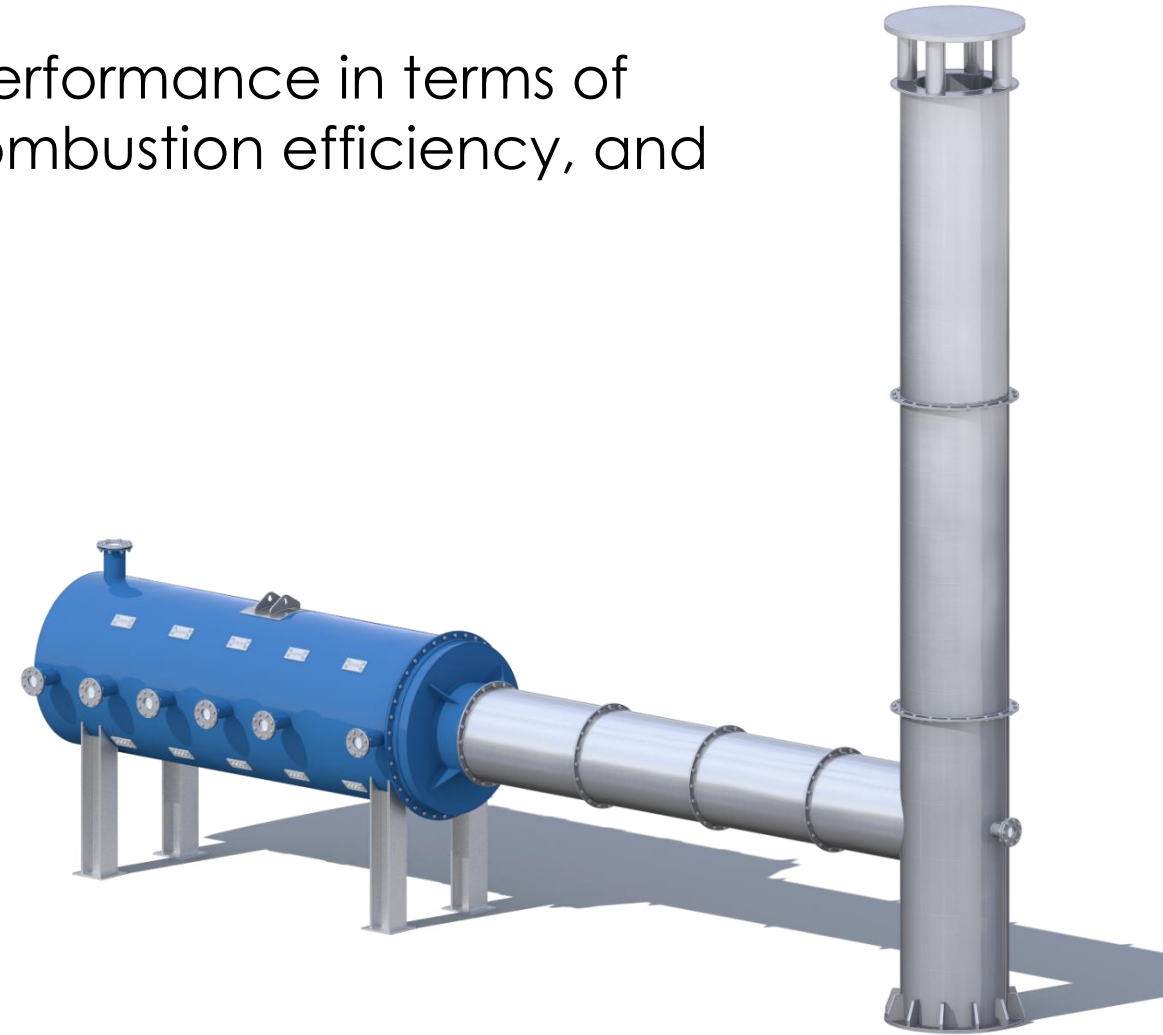
Technology Development

Horizontal Furnace – 500 kW

Initial build of industrial research furnace

Objective: Assess and optimize single burner performance in terms of flame characteristics, operability limitations, combustion efficiency, and emissions

- General info: 500 kW (1.7MMBtu/hr)
 - Physical orientation: horizontal
 - Control capabilities: Mixed or unmixed fuel blends for H₂-NG-BG-air (preheated) combustion
- Physical Design:
 - Steel shell, refractory-lined
- Experimental capabilities
 - Optical viewports (laser and imaging)
 - Traditional instrumentation ports
 - Emissions sampling at exhaust and along the flame



BLAZE

Box Furnace – 1 MW

Advancing Industrial Testing and Scale Up

Objective: Demonstrate and investigate multi-burner flame interactions, firing hydrogen, ammonia, biogas, natural gas blends in industry-relevant environments

- General info: 1 MW (3.4MMBtu/hr)
 - Physical orientation: box furnace with multiple burner mounts on opposing sides
 - Control capabilities: Mixed or unmixed fuel blends for H₂-BG-NG-air (preheated) combustion
- Preliminary Physical Design:
 - Steel shell, refractory-lined
- Experimental capabilities
 - Optical viewports (laser and imaging)
 - Traditional instrumentation ports
 - Emissions sampling at exhaust and at flame locations



Box Furnace – 1.5 MW

Accommodating indirect burner testing

Objective: Enable indirect burner and indirect firing testing arrangements in industry-relevant environment toward technology scale-up

- General info: 1.5 MW (5 MMBtu/hr)
 - Physical orientation: box
 - Control capabilities: Mixed or unmixed fuel blends for H₂-NG-air combustion
- Physical Design:
 - Steel shell, refractory-lined
- Experimental capabilities
 - Optical viewports (laser and imaging)
 - Traditional instrumentation ports
 - Emissions sampling at exhaust

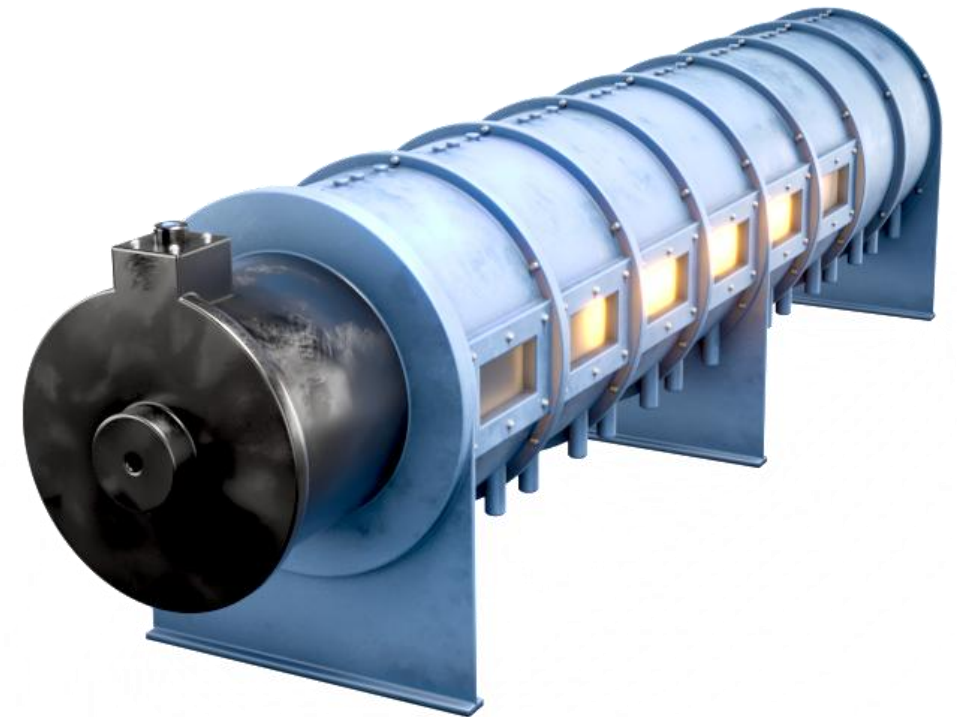


Boiler Simulator – 586 kW

Adjunct GTI Boiler Simulators

Objective: Test chambers to facilitate the development and testing of new boiler burners in realistic but controlled operation environment

- General info: 586 kW (2 MMBtu/hr)
 - Physical orientation: horizontal firetube
 - Control capabilities: Up to 0.7MMBtu/hr H₂ (pure or blends), fully manual and automated controls, preheated air
 - Draft control
- Physical Design:
 - Steel, water-cooled jacket
 - 12", 20", 24", and 32" diameter firing chambers
- Experimental capabilities
 - Optical viewports
 - Flue gas composition sampling and analysis
 - Temperature and pressure test ports
 - Air and fuel metering
 - Load simulation
 - Supplemental packaged boiler testing facility (hot water and steam, 2-5 MMBtu/hr capacity)



BLAZE Instrumentation Offerings



Cumulative capabilities across testbeds

Category	Equipment and Capabilities	Diagnostic Technique and/or Determinable Information
Flame and wall imaging	Access/viewing ports and windows	Excited species distributions (2D) via chemiluminescence
	Intensified camera(s) w/ filters (OH*, CH*, NH*, NH2*, NO*)	Species/temperature information (point/volume averaged) via optical emission spectroscopy
	Spectrometers (CCD & ICCD)	
	FLIR and Teledyne IR cameras	Wall temperatures via IR imaging
	Borescopes	
Emissions	Multiple traversable probe locations within chamber	Chamber/flame sampling via water-cooled probes and conventional analyzers
	Dedicated downstream global emissions port/probe	
	Full gas conditioning and emissions sampling suite (NO+NO2, THC, CO, CO2, O2, H2)	Far downstream sampling for global measurements
Temperature and heat flux	Reconfigurable instrumentation ports	Wall heat flux at various locations
	Heat flux gauges (OTS)	Chamber/flame temperature distributions
	Thermocouples (traversable)	
	Cooling water in/out temperatures + flow rate	Net heat flux of a given test article or cooled component
Flame & chamber dynamics	Phantom & Photron high-speed cameras	High-speed flame imaging (filtered and/or unfiltered)
	High-speed intensifiers	
	PCB, Kistler, and Kulite dynamic pressure transducers	Dynamic (time-varying) pressure via transducer measurements
Laser-based	Complete diode laser systems: NIR DFB, MIR QCL	Line-of-sight species (H2O, CO, CO2, NO, CH4) & temperature (at various axial locations)
	FTIR spectrometer w/ removable detector for in-situ measurements	
	YAG and dye lasers (10Hz and 30kHz) systems	OH-PLIF (limited by window placement)
Safety	Flame detectors (OTS/OEM), NETL CCADS	Flame/pilot presence, flame position, flashback
	Gas/leak detection (H2, NG, others)	Gas concentration and/or qualitative detection



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BLAZE Assets



Testbeds



Technology Development



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Technology Development



Challenge: Testing technologies for fuel flexibility requires expertise, infrastructure, and capabilities not easily accessible. Attaining the high-value data needed for technology development could pose high costs, safety risks, and long lead times.

Solution: *Leveraging BLAZE Assets for technology development*

- Industrial partners bringing their technology to a BLAZE testbed
- BLAZE technicians and researchers conduct testing of user hardware
- BLAZE engineers available to perform data analysis, computational modeling, and collaborative research
- Industry leverages new insights to improve their offerings

Technology Development - Burners



Challenge: Testing industrial burners with new fuel blends poses high risks, and high costs for both designers or product line users

Solution: *Leveraging BLAZE Assets for burner development*

- Experimental testing campaign using **custom feedstock blends** for new or existing designs
- Instrumentation for:
 - Flame characteristics
 - Species concentration, NO_x formation
 - Flashback
 - Heating Profiles
- CFD reactive flow modeling on supercomputers for:
 - Design optimization
 - Understand flame-to-flame interactions
 - Predictions for scale-up



Technology Development - Materials



Challenge: It is hard to predict the effects of harsh H₂ environments, with higher moisture content, H₂ embrittlement, etc.

Solution: *Leveraging BLAZE Assets for materials testing*

- Experimental testing campaign for **long duration exposure** to combustion with advanced fuel blends
- Tests can accommodate:
 - Poured refractory coupons
 - Materials samples of various sizes
 - Real-time optical monitoring
- Perform your own analysis or collaborate with NL materials expertise for:
 - Destructive and non-destructive testing for effects of embrittlement
 - Leverage eXtremeMAT-H2 consortium dedicated to H2 effects on new and existing metals



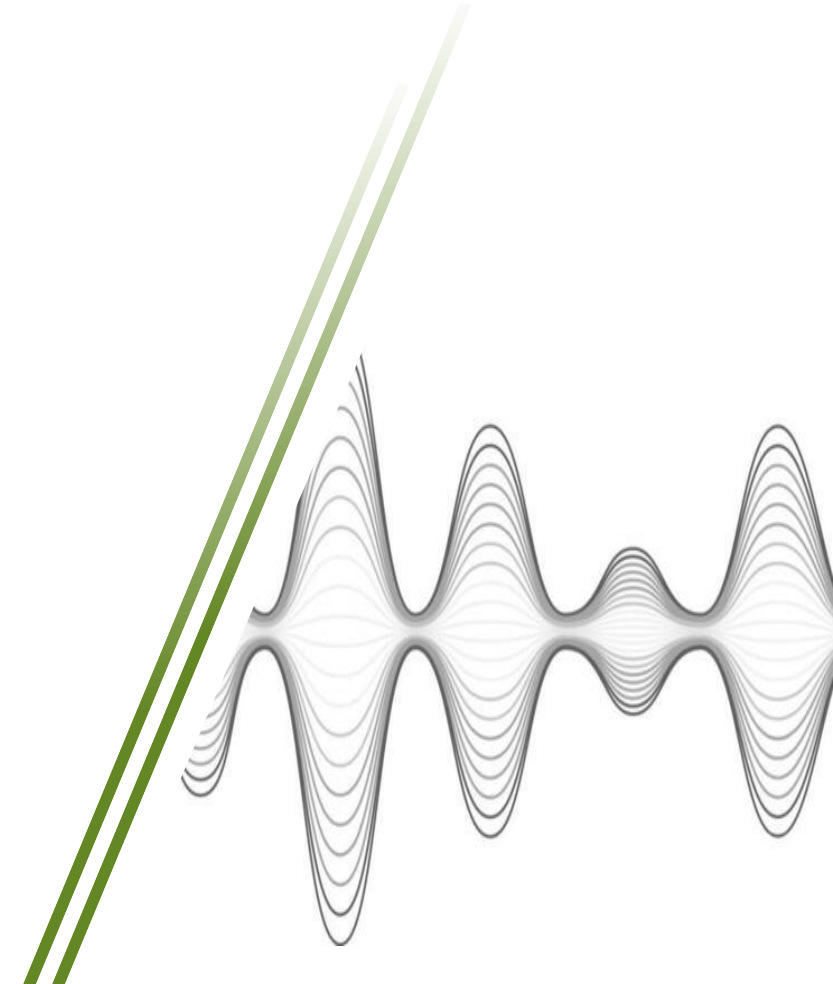
Technology Development - Sensors



Challenge: Industry requires reliable sensors for extreme environments, needing validated in a safe and reliable manor

Solution: Leveraging BLAZE Assets for sensors testing

- Experimental testing to **induce extreme** or **unwanted events**
 - Localized leaks for leak detection sensors
 - Flame blowout for flame detectors
 - Global exhaust emissions
- Benchmark against highly accurate laboratory instrumentation to prove accuracy and response time
- Use BLAZE CFD capabilities to:
 - Model gas dispersion scenarios (e.g., how a hydrogen leak spreads in a confined boiler house)
 - Determine optimal placement of your sensors for fastest detection



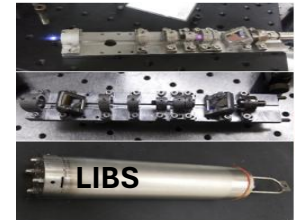
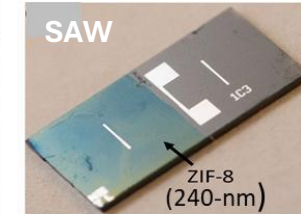
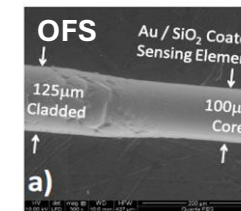
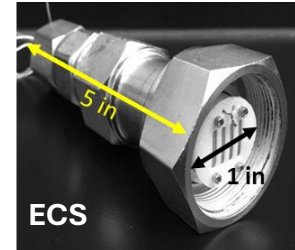
Sensor Materials for Critical Infrastructure and Extreme Environments

Advanced Sensors for Energy Efficiency, Safety, Resilience, and Sustainability

- ✓ Monitor systems and conditions
- ✓ Improve performance & efficiency
- ✓ Enhance reliability & safety
- Temp, acoustics, chemical, gas, corrosion
- Composite nano-materials, thin films & fiber optics, sensor devices development

Multiple Sensor Platforms

- Distributed Fiber Optics
- Surface Acoustic Wave
- Electrochemical
- LIBS
- Raman



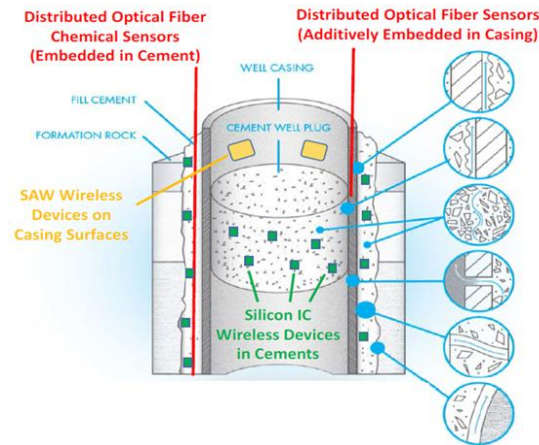
ENERGY DELIVERY & STORAGE



Pipelines: Monitor corrosion, gas leaks, T, acoustics to predict/prevent failures. NG, H₂, CO₂

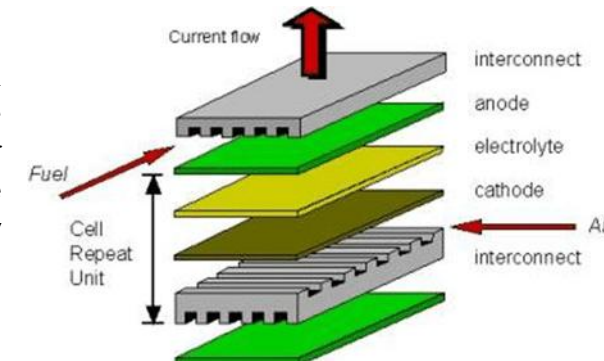


Grid: Transformer, powerline failure prediction, fault detection, state awareness



Subsurface: Wellbore integrity, failure prediction, leak detection. Geologic storage of CO₂, H₂/NG, or abandoned wells.

SOFCs: Fuel concentration & temperature gradients for improved lifetime and efficiency



Distributed Fiber Optics Sensor Development



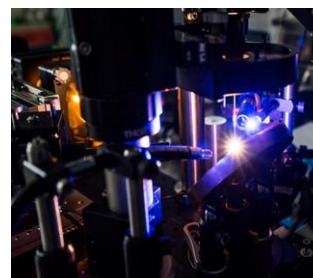
BLAZE

LABORATORY SENSOR
EVALUATION



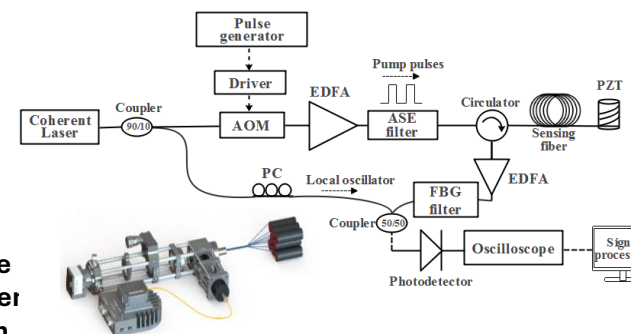
Custom Reactors to test sensors.
Gases: H₂, CH₄, CO, CO₂, N₂, O₂
Ambient pressure up to 1000°C
Pressurized >1000psi

FIBER OPTICS DEVELOPMENT



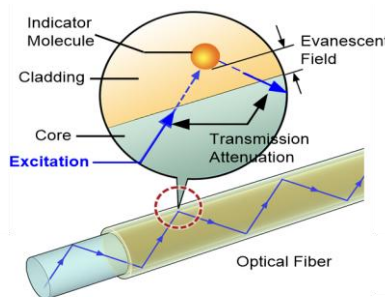
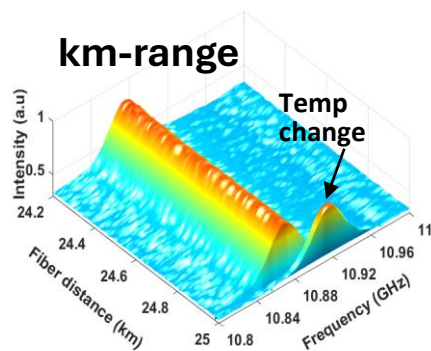
Single Crystal YAG and Sapphire fibers for sensing to 2000°C. Laser Heated Pedestal Growth System. CO₂ laser to form long (20 m) single crystal fibers. Patented control algorithm

DISTRIBUTED INTERROGATION DEVELOPMENT

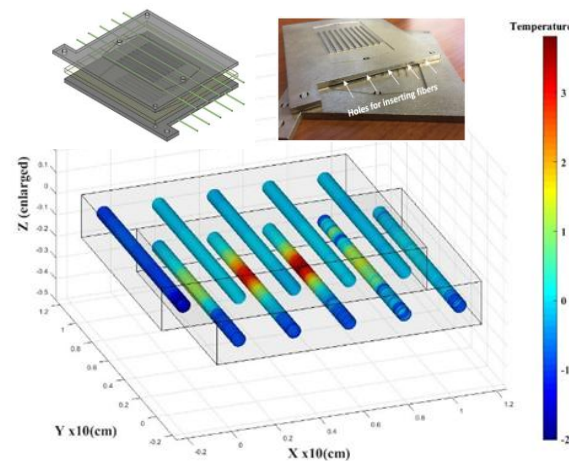


Multiple optical backscattering methods being employed to enable distributed measurement of multiple parameters

Temperature, Strain, Acoustic, Vibration, Gas Chemistry, pH, Corrosion, Gas Leak Detection

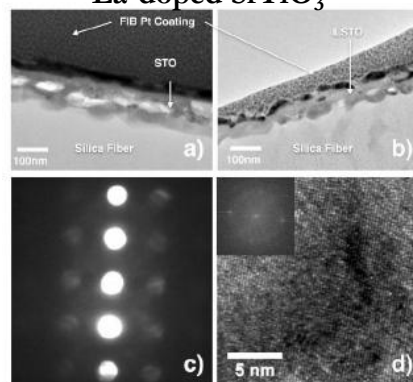


FUNCTIONAL SENSING MATERIALS BY DESIGN FOR HARSH ENVIRONMENTS



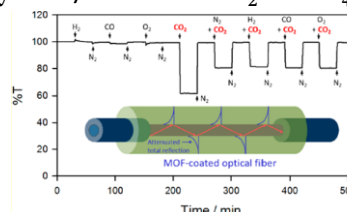
Real-time 2-D temperature distribution measurements in situ for SOFCs

La-doped SrTiO₃

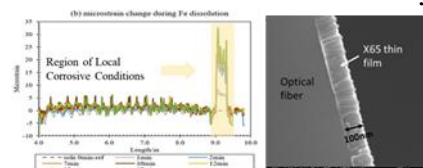


Functional coating enables SOFC fuel gas composition monitoring

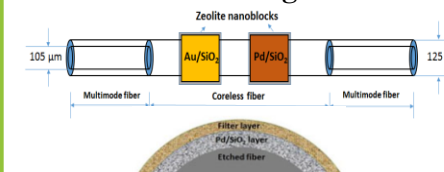
Micro-Porous Gas Absorbent
Polymers/MOF for CO₂ & CH₄ Detection



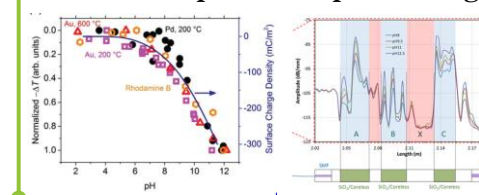
Metallic Films as Corrosion Proxy



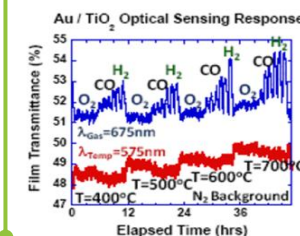
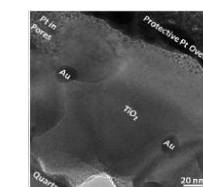
Simultaneous H₂ and Temp Monitoring



Nanocomposites for pH Sensing



Nano-Composites:
Au-TiO₂, Au-SiO₂



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Argonne
NATIONAL LABORATORY

Technology Development – Scale Up

Challenge: Scaling technology from lab test to an industrial facility is fraught with non-linear scaling challenges

Solution: Leveraging BLAZE physical, digital and intellectual assets to de-risk technology scale-up

- Utilize robust experimental testing using advanced feedstock blends and diagnostics
 - Observe flame behavior and characteristics
 - Gather reliable, high-fidelity validation data
- Create validated CFD models that are:
 - Demonstrated on baseline technology at various scales
 - Tailored by combustion modeling experts
 - Fit to custom datasets gathered from testbeds
- Use BLAZE supercomputing to:
 - Expand simulation parameters to commercial scale
 - Reduce capital risk of adopting new technologies



Contract Vehicles

Defining Intellectual Property (IP), research objectives, funding structures, & publishing considerations

FUEL-FLEXIBLE COMBUSTION TESTING

- Evaluate adaptive industrial heat technologies on BLAZE test beds to reduce fuel costs and boost efficiency.

PHYSICAL AND DIGITAL COLLABORATION

- Combine physical testing (furnaces, boilers, advanced diagnostics) with digital tools (CFD modeling, AI) to accelerate commercialization.

SERVICE CENTER

- Industry funds BLAZE efforts in whole OR in part for unique data analysis or models (LCA, TEA, Digital Twin, etc.)

Contributed Funds Agreement (CFA)

- Best for **"Test-as-a-Service"** where partners fund NETL to perform specific **non-R&D testing or modeling**.
- Governed by a standard agreement and a **project-specific SOW**.
- Explicitly covers **non-R&D services** where **no new Intellectual Property (IP)** or inventions are expected to arise.
- **Requires 100% upfront funding** (or incremental 60-day advances for larger projects).

Cooperative Research And Development Agreement (CRADA)

- Ideal for collaborative research where **both NETL and partners actively participate**.
- Governed by a collaborative agreement and a **project-specific SOW**.
- **Supported by** partner funds-in and/or in-kind **contributions from both parties**.
- **Generated data can be protected** from disclosure for up to 5 years.
- Partners **have option to license** newly developed inventions.

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