About the Webinar

NETL Energy 101

We hope you will leave the webinar with knowledge about:

• Better understanding of the research being conducted at NETL in Advanced Manufacturing and Rare Earth Metals and how successes in research may impact the region and the nation

• How to engage and interact with NETL

• What is the Regional Workforce Initiative and how can you engage with the RWFI
I. Welcome Message and background from the NETL Regional Workforce Initiative Team
   • Welcome to NETL!
   • What are the research thrusts at NETL?
   • What is the NETL RWFI?

II. Energy 101- Advanced Materials and Manufacturing
   • What is advanced manufacturing?
   • What type of research is being conducted at NETL about advanced manufacturing/composites and advanced materials?
   • What type of skills are necessary for the advanced manufacturing worker?
   • What’s the potential economic impact of success?

III. Energy 101- Rare Earth Metals
   • What are Rare Earth Metals and why are they important?
   • What are the research challenges?
   • What is the potential economic impact of success?

IV. Conclusion- How to stay connected to NETL and the Regional Workforce Initiative
NETL Regional Workforce Initiative (NETL RWFI)

A Focus on Energy and Advanced Manufacturing Regional Workforce Readiness and Development
NETL Regional Workforce Initiative Mission

A Platform For:

• Communication and collaboration with regional/national stakeholders and partners, DOE and other federal agency partners

• Connecting public investment in energy and advanced manufacturing NETL R&D to national and regional economic development, education, and jobs

• Discussing energy and manufacturing regional and national workforce skills gaps generally and specifically to NETL’s core R&D

How We Engage:

• Monthly E-Note Email Bulletin
• On Campus Engagements
• Webinars and Webcasts
• NETL RWFI Website
• Participation and representation at regional and national energy and manufacturing workforce meetings and groups
RWFI aligns to the Administration’s efforts to connect R&D investment to economic growth, job growth, and development of a skilled technical workforce.

- OMB Memorandum to Agency Heads on FY 2020 Administration Research Development Budget Priorities
- EO-Establishing the President’s Council for the American Worker
- EO-Establishing Apprenticeships in America
- EO-Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure
RWFI Outreach, Meetings, Webinars, and Workshops

Consistent, meaningful, outcome driven, engagement

- Initial 2017 NETL RWFI Strategic Plan Released
- First Regional Community College Workforce Meeting and NETL Morgantown Tour
- ARC Annual Summit - NETL and Regional Stakeholders Workforce Panel
- Second Regional Community College Workforce Meeting and NETL Tour
- Developmental District Association of Appalachia - NETL/ORNL Workforce Panel
- NETL Coal to Products Workforce Workshop
- NETL RWFI Energy and Advanced Manufacturing Jobs and Workforce Data Webinar
- NETL RWFI Strategic Partnership & West Virginia NEP Meeting and Tour
- Westmoreland Community College Energy Summit - NETL Presentation
- Appalachian Higher Education Network 2018 Annual Conference
- America Makes Apprenticeship Works Roundtable
- Tri-State Shale Coalition Workforce Panel
- Appalachian Regional Commission NETL Meeting and Tour
- NETL Strategic Partnership & West Virginia NEP Meeting and Tour
- Earth X Summit and Earth X E-Capital Innovation Summit
- NETL Participation

Events:
- Displaced Coal Workers Training Programs Webinar
- ARC Community College Cohort Industry Meeting
- Kentucky Shaping our Appalachian Region Conference (SOAR)
- Tri-State Oil and Natural Gas Workforce Development Roundtable
- Economic Development Stakeholders Workforce Meeting at NETL Morgantown
- Appalachian Regional Commission NETL Meeting and Tour
- NETL RWFI Website Launch
- NETL RWFI Energy and Advanced Manufacturing Jobs and Workforce Data Webinar
- Appalachian Higher Education Network 2018 Annual Conference

- 2017
  - May: CMU, DOD, DOE, NETL and Allegheny Conference Meeting on Veterans Workforce Training
  - June: Launch of NETL RWFI E-Note Monthly
  - Aug: Tristate Energy and Advanced Manufacturing (TEAM) Consortium Kickoff Meeting
  - Sept: Tri-State Shale Coalition Workforce Panel
  - Oct: Community Colleges of Appalachia Fall Conference - NETL RWFI Presentation
  - Nov: NETL Strategic Partnership & West Virginia NEP Meeting and Tour
  - Dec: America Makes Apprenticeship Works Roundtable

- 2018
  - Feb: Westmoreland Community College Energy Summit - NETL Presentation
  - Mar: Earth X Summit and Earth X E-Capital Innovation Summit
  - Apr: NETL Participation
  - May: Appalachian Higher Education Network 2018 Annual Conference
• Continued outreach to regional stakeholders, such as the Appalachian Regional Commission (ARC)

• Planning for RWFI webinars on:
  • Economic Development
  • Energy Technology 101 (March 28\textsuperscript{th} 2019)
  • US Energy and Employment Report PA/OH/WV Data

• Potential on-campus events:
  • The future of work in the national and regional fossil energy sector
  • Energy and advanced manufacturing industry workforce roundtable
  • Innovation and Entrepreneurship in Energy and Advanced Manufacturing
Core Competencies & Technology Thrusts

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For More Information, Contact Anthony Armaly
anthony.armaly@netl.doe.gov
+1-412-386-6040
www.netl.doe.gov
NETL Advanced Manufacturing Overview:
For NETL Regional Workforce Initiative
Energy 101 Webinar

Solutions for Today | Options for Tomorrow

James M. Ferguson
S&T Strategic Partnerships
March 28, 2019
NETL Advanced Manufacturing Activities

• **Research: Extramural and Intramural**
  • Up to ~ 20-30 Financial Assistance Awards
  • Up to ~ 5-10 R&IC Field Work Proposals (FWPs)
  • Up to ~ 3-5 R&IC Small Business Innovation Research (SBIR) Awards

• **Memberships:**
  • America Makes (Active)
  • RAPID Manufacturing Institute (Pending)
  • Advanced Robotics for Manufacturing (ARM) Institute (Pending)

• **Collaborations:**
  • MOU with Oak Ridge National Lab (signed March 2018)
  • NextManufacturing Consortium at Carnegie Mellon University
  • Other Government/Industry/Academia
Advantages of Advanced Manufacturing

Advanced Manufacturing (AM) definition: Use of innovative technologies, improved processes, and management methods to improve the manufacturing of products.

• Reduced transportation costs
• Overall improved performance
• Fewer materials wasted (reduced inventories)
• Extreme performance requirements of turbines requires AM solutions
• Demonstrated history creating AM technologies and high value gas turbine parts
• NETL has experienced project managers to execute the subject program
• Technical assistance to thousands of industrial plants
• Reduced climate and environmental impact
• Improved national energy security and competitiveness throughout the supply chain

GOAL
Within 5 years, NETL becomes a leader and major force in the development of fossil-based AM technology improvements (e.g., cost reduction, efficiency, reliability, time to market, environmental footprint) across the fossil energy value chain.
A 21st century energy transition, a new era of energy innovation, and energy market expansion present a golden opportunity to boost U.S. employment.
Fossil-focus in Advanced Manufacturing

Intersection of fossil energy and advanced manufacturing

- Nano-Manufacturing
- Big Data
- Artificial Intelligence
- Process Intensification (RAPID)
- Cyber-Physical
- Additive Manufacturing (America Makes)
- Machine Learning
- Robotics (ARM)

Processing and Nano-Manufacturing

Data Analytics “Big Data”

Cyber Physical Modeling

Additive Manufacturing
NETL Strengths: Advanced Manufacturing in Fossil Energy

Compelling Applications

**STRUCTURAL MATERIALS**

**GAS TURBINES**

**SENSORS & CONTROLS**

**CARBON CAPTURE**

**HEAT EXCHANGERS**

**SOLID OXIDE FUEL CELLS**
Materials Engineering & Manufacturing

Functional and Structural materials solutions to enable efficient and effective power cycles and resource recovery

Materials:
- Soft materials
- Engineered nano-materials
- Advanced alloys
- Composites & ceramics

Current Thrusts:
- Heat resistant & corrosion resistant alloys
- Magnetic alloys
- Environmental barrier coatings & materials
- Sensors for process monitoring & system integrity
- Carbon products from coal
- Rare earth elements from coal & coal by-products
- CO₂ capture and utilization materials
- Oxygen carriers
NETL Strengths: Coal-based Carbon Nanomaterials

**Domestic Char**
(Sample from Virginia Carbonite)

**Coal Processing Technology**

**Low Cost Graphene Inks/Fluids**

**Carbon Quantum Dots**

**Graphene-Enhanced Cement**

**Engineered Plastics**
Possible Modern Applications for Coal-derived Carbon Materials

New branches & limbs for a modern coal products tree
This is a small example of what scientists think may be possible

Stain & Water Resistant Textiles
Electronic Displays
Pigments, Dyes, & Paints
Optical Brighteners
Photovoltaics & LEDs

Carbon Fiber
3D Printing Materials
Additives For Construction Materials
Carbon Nanomaterials
Domestic Coal for Materials Manufacturing

SMART TEXTILES
Stain/Water Resistant Clothing

3D PRINTING MATERIALS
Fluids, Filaments, Plastics, & Devices

CARBON NANOMATERIALS
Graphene, Graphene Oxide, & Carbon Quantum

DOMESTIC COAL for MATERIALS MANUFACTURING

PLASTIC COMPOSITES
Enhanced Plastics

ENERGY STORAGE MATERIALS
Supercapacitors & Electrode Materials

STRUCTURAL & BUILDING MATERIALS
Structural Cements
Converting Coal Into High-Value Added Products

Current and Potential Stakeholders for NETL

Consortium with Leading Coal-Producing States, Community Colleges, & Economic Development Programs

- SMART TEXTILES
  - Stain/Water Resistant Clothing

- PLASTIC COMPOSITES
  - Enhanced Plastics

- STRUCTURAL & BUILDING MATERIALS
  - Structural Cements

- CARBON NANOMATERIALS
  - Graphene
  - Graphene Oxide
  - Carbon Quantum

- 3D PRINTING MATERIALS
  - Fluids
  - Filaments
  - Plastics
  - Devices

- ENERGY STORAGE MATERIALS
  - Supercapacitor
  - Electrode Materials
Converting Coal Into High-Value Added Products

Current and Potential Stakeholders for NETL

SUPPORTED BY
Community Colleges and State Economic Development Programs

Consortium with Leading Coal-Producing States
High-Value Carbon Products from Domestic Coal

COAL FEEDSTOCKS
$30-60/ton

MATERIALS MANUFACTURING

CARBON PRODUCTS
Carbon Fiber & Structural Composites
$100,000/ton

3D Printing Materials
$70,000,000/ton

Carbon Nanomaterials
$100,000,000/ton

NEW ECONOMIC OPPORTUNITIES
Jobs, Products, Markets
### Advanced Manufacturing – Key Partnerships

| **Carnegie Mellon University (CMU)** | The CMU NextManufacturing Center is one of the world’s leading research centers for additive manufacturing (AM), commonly known as 3-D printing. The center leverages knowledge from across disciplines to develop an entirely new approach to AM: design optimization, materials selection and characterization, process parameter mapping, software development, final part inspection, and qualification. NETL has the potential to significantly benefit from a R&D partnership with the NextManufacturing Consortium. |
| **University of Pittsburgh (Pitt)** | NETL funds several projects at the University of Pittsburgh, including an ongoing multiyear project through the Swanson School of Engineering on a project to develop an innovative approach to providing improved thermal protection for hot-section components in modern and future gas turbines. This project makes use of Oxide Dispersion Strengthened (ODS) material to form a thermal-oxidation protection layer over a single crystal superalloy substrate, in conjunction with the concept of near-wall cooling modules or coupons. |
| **Penn State University (PSU)** | In 2016, PSU was selected by the DOE and NETL as the lead institution to establish the University Coalition for Fossil Energy Research, with the goal to bring together researchers from multiple universities across various disciplines to advance fossil-based energy technologies. This six-year initiative is being funded for $20 million. |
| **West Virginia University (WVU)** | In 2017, WVU joined RAPID in an effort to turn natural gas into valuable products. WVU was invited to participate as part of the core team to strategize the American Institute for Chemical Engineering. West Virginia’s vital resources are abundant, yet untapped. WVU is leading advanced manufacturing research initiatives to lead growth and opportunity in the conversion of natural gas and other hydrocarbons utilizing smaller modular manufacturing reactors. The idea of “mobile factories” has the potential to give WVU a lead in the right direction of a positive economic outlook. |
| **America Makes (National Additive Manufacturing Innovation Institute)** | NETL joined America Makes (National Additive Manufacturing Innovation Institute) in December 2016 to team with the nation’s leading additive manufacturing and 3D-Printing technology research, discovery, and creation company that also offers a close proximity to the Appalachian region. |
| **RAPID Manufacturing Institute (AIChE)** | In December 2016, the DOE announced that the Rapid Advancement in Process Intensification Deployment (RAPID) Manufacturing Institute of the American Institute of Chemical Engineers (AIChE) will be the newest, and tenth, member of the nation’s network of Manufacturing USA Institutes. This partnership will enhance NETL’s relationship with manufacturing R&D across government, university, and private sectors. |
Advanced Manufacturing: A Regional View

The Tri-State Area’s Major Organizations

**Cleveland, OH:**
The Manufacturing Advocacy and Growth Network (MAGNET, the Ohio Manufacturing Extension Partnership)
Case Western Reserve University

**Youngstown, OH:**
America Makes
Northeast Ohio Additive Manufacturing Cluster
Youngstown Business Incubator
Team NEO/Jobs Ohio
Youngstown State University

**Pittsburgh, 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

**Morgantown, WV:**
West Virginia University
WV Manufacturing Extension Partnership

**Charleston, WV:**
Mid-Atlantic Technology, Research, and Innovation Center
West Virginia Manufacturers Association
TechConnect West Virginia

**Huntington, WV:**
Robert C. Byrd Institute for Advanced Flexible Manufacturing
Marshall University
Appalachian Coal Country: Major Stakeholders

Initiating & Enhancing Collaborative Partnerships

INDUSTRY PARTNERSHIPS

GOVERNMENTAL PARTNERSHIPS

ACADEMIC PARTNERSHIPS

NONGOVERNMENT PARTNERSHIPS

Tri-State University Energy (TrUE) Alliance

Other logos and partnerships are also shown in the image, including various universities, energy companies, and government organizations.
### Attachment B: Tri-State TalentNET (ShaleNET/ManufactureNET) Occupational Pathways

<table>
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<th>Degree Level</th>
<th>Industrial Maintenance</th>
<th>Automation Robotics</th>
<th>Welding</th>
<th>Tooling &amp; Machining</th>
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<td>&quot;Process Technician&quot;</td>
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**Industries/sectors relevant for each of these occupational pathways:**
- Construction
- Oil & Gas
- Advanced Manufacturing...

**Oil & Gas**
- Electrical Engineer
- Machine Tool Operator

**Plastics Mfg.**
- Chemical Engineer
- Material Engineer
For More Information, Contact James Ferguson
James.Ferguson@netl.doe.gov
(412) 386-6043
www.netl.doe.gov
Rare Earth Elements

A Promising Opportunity

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Thomas Tarka (Thomas.Tarka@netl.doe.gov; 412-386-5434)

TTCs: John Baltrus, Evan Granite, Bret Howard,
Kelly Rose, W. Morgan Summers

Key Contributors: Christina Lopano, Circe Verba, Mac Gray, and too many others to list.
Rare Earth Elements (REE) FWP

BLUF

NETL researchers have made significant advances in developing transformational technologies to reduce the cost and environmental footprint of REE production from coal and related feedstocks:

• Produced “Ore Quality” REE from several feedstocks (>2wt%)  
• Developed enabling technologies (e.g. sensors) and performed valuable market and systems analyses, both of which reduce risk to deployment 
• Developed methods to locate high concentrations of coal and related REE reserves

EY19 work focuses on maturing several transformational separations pathways while simultaneously driving innovation through development of tools and capabilities to unlock domestic REE resources:

• Repeatable results at increasing scales (from 1 milligram to grams)  
• Identifying commercialization opportunities and partners 
• Developing the tools to reduce commercialization time and risk (CFD & Systems Analysis) 
• Identifying the best coal-related resources and reserves for a domestic REE industry
Outline

• Background
  • Brief Overview of REE
  • Challenges and Opportunities for REE Production from Coal
  • REE FWP Strategy
  • Where We’ve Been

• Recent Major Accomplishments
  • Real-Time, Portable Detection Equipment
  • Production of “Ore Quality” REE from Several Coal-related Feedstocks
  • Continued Strong SEA Support
  • Taking the Next Step in Locating Promising Resources

• The Path Forward
What are Rare Earth Elements (REEs)?

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Average total crustal concentration = 184 ppm

*Wedephol, 1995
Uses for Rare Earth Elements

- **INDUSTRY**
- **ELECTRONICS**
- **RENEWABLE RESOURCES & GREEN TECHNOLOGY**
- **CHEMICAL**
- **NATIONAL DEFENSE**
- **MEDICAL**

Average total crustal concentration = 184 ppm

*Wedephol, 1995*
Rare Earth Elements Market

- Annual global market ~$5 billion in 2015
  - U.S. consumes ~11%, by volume
  - Almost all REEs are imported

- Majority of REEs imported as part of finished goods, not raw materials
  - US imported $2.4 trillion worth of REE-containing finished goods in 2017
  - Electronic equipment imports:
    - ~$357 billion in 2017 (14.8% of total)
  - Phone devices (e.g. iPhone) almost a third of that at $113 billion
  - Cellular phone can contain as many as 16 different REEs

- Market remains complicated
  - Risks of substitution
  - Current oversupply
  - All global enrichment and processing is done in China

Source: http://www.worldstopexports.com/united-states-top-10-imports/
Most used REOs were:

- Cerium Oxide (32%)
  - Catalyst related products and glass polishing powders and additives
- Lanthanum Oxide (31%)
  - Catalyst related products and glass polishing powders and additives
- Neodymium Oxide (18%)
  - Permanent magnets
- Yttrium Oxide (10%)
  - Ceramics, pigments and glazes, and glass polishing and powder additives
- Praseodymium Oxide (5%)
  - Permanent magnets

• Global consumption of LREOs increased at a CAGR OF 2.8%, while global consumption of HREOs increased at a CAGR of 1.5%
Estimated Global REE Production 2017

- Total REO Production Estimated at 170,000 tonne/year
- Total REO Demand Estimated at ~150,000 tonne/year
- US accounts for ~11% of Global Demand
- Actual Chinese production >92% including illegal mining

Source: Argus Media

Rare Earth Deposits

Mountain Pass (Bastnasite) ~8% REO

Bayan Obo (Bastnasite) ~6% REO

Southeast Guangdong (Xenotime) ~0.5% REO

Mount Weld (Monazite) ~8% REO

Coal <0.1% REO

Source: Argus Media
REE from Coal: The Challenge

Where do we get it? and What do we produce?

• Low Concentration in Coal Feedstocks
  - Ranges from parts per billion (ppb) in AMD to ~1,500 parts per million (ppm) in certain ashes
  - Global REE ores in current use range from 0.5 wt% (5,000 ppm) to 50wt% (500,000 ppm) with major deposits generally near 8wt%

• Currently No Domestic Supply Chain
  - No clear domestic off-take except for “saleable” (>90+% ) REO or “REO baskets”
  - Creates uncertainty as to what concentration domestic processes should target

• Very Broad Problem
  - Almost too many coal and related feedstocks to target: which is best?
  - Are REE the product or co-product?
  - Each coal-related feedstock is different, even within same category
REE from Coal: A Unique Opportunity
Importance to the Fossil Energy and DOE Mission

• National Security
  • 5% of total domestic demand is deemed “critical” by the Department of Defense (DoD)
  • Required for numerous critical industries (energy, manufacturing, etc.)
  • Necessary for numerous clean energy technologies which have been deemed a national priority

• Power the U.S. Economy and keep electricity affordable:
  • Additional value streams make coal more cost competitive & keep electricity prices low
  • Drives U.S. coal competitiveness in international markets, driving exports
  • Creates or maintains jobs in economically hard hit regions, such as Appalachia
  • Provides an important new domestic resource, allowing more manufacturing to locate in the U.S.

• Environmental Stewardship
  • Opportunity for remediation, and reducing waste streams from coal production & use
  • Beneficiated coal will burn more efficiently, creating less emissions
  • Produce REEs with a dramatically lower environmental footprint than overseas
Coal Refuse Material & Combustion By-Products

Southern West Virginia coal preparation plants have produced over 1.8 billion tons of coarse refuse material over the last 60 years

- Potential value of $31.5 billion at 100% recovery
- Potential value of $9 billion at just 30% recovery

56 active coal preparation plants produce a course refuse with a potential of $3.2 billion annually in the our region.

(Source: University of Kentucky)

“By the year 2000, we will not be wasting our coal ash, in which geochemists have shown there is a notable concentration of rare elements, such as germanium and rare earths. We will be recovering those elements, which by then will be critical materials in our economy.”

- Dr. Edward Steidle
  Dean, PSU College of Earth & Mineral Sciences, 1952
  (Inducted into the National Mining Hall of Fame, October 23, 2015)
Acid Mine Drainage Opportunities

- WVU reports that the REE concentration in some acid mine drainage (AMD) sludge samples they have analyzed exceeds most Chinese deposits, and has more of the valuable heavy REE.

- WVDEP’s Office of Special Reclamation estimates the potential REE value AMD precipitates (sludge) at one of their treatment sites at $1.9 million.

- Significant environmental benefits could come from cleaning up legacy coal refuse disposal sites and wet impoundments for post-combustion ash.

- The tailings/rejects from a future REE recovery process could be used as structural fill to remediate surface mine sites.
• Understanding the “Where” and “How” (Characterization)
  • Driving the understanding of how REEs occur in coal and by-products
  • Developing the technologies needed for prospecting and new production means

• “Cheap” and Environmentally Benign Production (Separations)
  • Producing ore-quality and greater REE from coal and related materials
  • Combining processes for further efficiency and enrichment
  • Maturing promising transformational separations technologies and continuing to push the envelope

• Smarter, Not Harder (CFD & Systems Analysis)
  • Developing the cutting edge CFD models to help drive commercialization and scale up
  • Identifying process bottlenecks, research targets, and market opportunities through systems analysis

• Driving Innovation, Unlocking the REE Potential of Coal
  • Developing the tools for REE prospecting in coal basins
  • Identifying the best resources for exploitation – be it fly ash with high Ca content, underclays, or raw lignite
EY18 Major Accomplishments

Overview

• **Enabling Technologies**
  • Portable Devices for Accurate, Real-Time Detection of REE
  • Models that allow complex reactor modeling without needing to perform expensive experiments

• **Separations and Enrichment**
  • *Produced "Ore Quality" REE (i.e. >2wt%) from 3 Feedstocks*
  • Pursuing three promising pathways that address different feedstocks, from Fly Ash to AMD
  • Transformational Separations Research has Potential for Dramatic Cost Reductions

• **Systems Engineering and Analysis**
  • Understanding Domestic REE Needs through an Embedded Demand Database
  • Quantifying Benefits of Domestic Production by Looking at Existing REE Processes

• **Developed First Model to Predict Where REE Might be Concentrated in Coal**
  • Geo-spatial, Geologic Assessment Methodology to understand where REE occur
  • Currently being validated for Western coals, Appalachia is next
Thanks for your Attention!
• Thank you for your participation!
• NETL.gov/RWFI
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• NETL RWFI E-Note

• US Energy and Employment Report Data for PA/WV/OH
• Future Energy 101 Webinars