Advanced Coal Processing Program

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NETL’s Advanced Coal Processing Program

Program Goals
- Enhance the value and applications of domestic coal and coal wastes
- Develop new high-value products derived from domestic coal and coal wastes
- Advance laboratory and pilot-scale technologies
- Expand coal databases to inform domestic and global customers

Program Focus Areas
- Coal to Carbon Products
- Feedstock Upgrading
- Coal Properties Database
Expanding the Coal Value Chain

- Exciting opportunities to expand use of coal
- Advantages over other carbon-based feedstocks
  - Abundant and low cost
  - High-carbon density
  - Enables low cost, high-volume production of carbon materials
- Challenges
  - Optimizing product and process performance

NETL’s Advanced Coal Processing Program
Product and Application Market Potential

Advanced Coal Processing Program

- Program is focusing on high-value and high-growth products
- Current products and applications
  - $96.3B global market value by 2023
  - CAGR of 9.2%
- Tremendous potential for domestic coal
**Program and Funding History**

**Recent Funding Opportunities**

<table>
<thead>
<tr>
<th>Funding Opportunity</th>
<th>Issue Date</th>
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<tbody>
<tr>
<td>FOA-0001992: Maximizing the Coal Value Chain</td>
<td>3/4/2019</td>
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<tr>
<td>FOA-0002185: Coal-derived materials for building, infrastructure, and other applications</td>
<td>4/10/2020</td>
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<tr>
<td>FOA-0002438: Design, R&amp;D, Validation, and Fabrication of a Prototype Carbon-Based Building</td>
<td>12/11/2020</td>
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<tr>
<td>FOA-0002405: Advanced Coal Waste Processing: Production of Coal-Enhanced Filaments or Resins for Advanced Manufacturing and Research and Development of Coal-Derived Graphite.</td>
<td>04/16/2021</td>
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Active Projects

- Program has 31 active projects
  - Three focus areas
    - Feedstock upgrading
    - Coal properties database
    - Coal to carbon products
- Carbon Products Include:
  - High Value
    - Graphene, quantum dots, conductive inks, battery anodes, synthetic graphite, and supercapacitor materials, carbon fibers
  - High Volume
    - Building materials, carbon foam, composites, roofing materials.
Feedstock Upgrading

Pilot Plant Testing and Development

**Carbon Fuels LLC**
FOA: 1849
Total Award Value: $3,166,443

The Novel Chartfuel Coal Refining Process 18 Tpd
Pilot Plant Project for Co-Producing an Upgraded Coal Product and Commercially Valuable Co-Products

**Minerals Refining Company, LLC**
FOA: 1849
Total Award Value: $1,806,857

Pilot-Scale Testing of the Hydrophobic-Hydrophilic Separation Process to Produce Value-Added Products from Waste Coals

**TOTAL AWARD VALUE**
~$4.97 MILLION
An Authoritative “Smart” American Coal Database & Virtual Beneficiation Platform to Optimize Coal Sources for Efficient and Effective End Uses

- Provides coal property, geochemical, and infrastructure data to coal producers and consumers
- [https://edx.netl.doe.gov/geocube/](https://edx.netl.doe.gov/geocube/)
Coal to Building Materials

Revolutionizing Sustainable Building and Construction Materials

• High-volume and high-value products for coal
• Opportunities for coal
  • Increase product performance
  • Increase building energy-efficiency
  • Reduce product cost
• Products include
  • Carbon foam, roofing tiles, siding, decking, insulation, joists/studs, sheathing, and block
• FOA 2185: Building Materials
  • 14 projects recently selected to receive $8.7 million
• FOA 2438: Prototype Carbon-based Building
FOA 2185: New Selected Projects

Coal-Derived Materials for Building, Infrastructure, and Other Applications

- **Building Materials: 10 Projects**
  - Coal-derived composites and pipe
  - Siding materials and architectural panels
  - Coal-based bricks & blocks and pavements
  - Carbon foam
  - Prototype carbon-based building

- **High-Value Carbon Products: 4 Projects**
  - Graphene (2)
  - Silicon-carbon (Si-C) composite anode materials for lithium-ion batteries
  - Coal-derived quantum dots (CQDs)
Example Coal to Building Material Projects

**Semplastics**
SBIR Grant
Phase 1 – 2018
Phase 2 – 2019

Coal-core composite (CCC) for roofing tiles and other products

**Ohio U**
FOA: 1992
Awarded Sept. 2019

Coal plastic composite (CPC) for decking boards and other products

**Battelle**
FOA: 1992
Awarded Sept. 2019

Coal to polyurethane (PU) foam (solid) products

**NETL - RIC**
FWP-1022432
Initiated 2018

Coal-derived graphene used as an additive in ordinary Portland cement
Coal to Carbon Fiber

Producing High-Performance Materials from Coal

- Carbon fibers are strong light-weight materials
- Carbon Precursors include Polyacrylonitrile (PAN), Rayon, and coal tar pitch
- Program supports developments to enhance carbon fiber properties and production
- High carbon content, lower cost of coal tar pitch enable lower cost production
Coal to Carbon Fibers

Ramaco Carbon
FOA: 1992
Awarded Sept. 2019

UKY
FOA: 1992
Awarded Sept. 2019

Ramaco Carbon
FOA: 1992
Awarded Sept. 2019

ORNL and UKY
FEAA155

U. of Utah
FOA: 1992
Announced Jan. 2020

Raw coal feedstocks into pitch and carbon fibers

Melt spinning coal-derived pitch into fiber

High-quality carbon fiber precursor material

C4WARD: Coal Conversion for Carbon Fibers and Composites

Isotropic and mesophase coal-tar pitch for carbon fiber production
Coal to Carbon Electrodes

George Washington U

FOA: 1992
Awarded – Sept. 2019

High value (Li-ion grade) “potato” graphite

Physical Sciences
SBIR Grant
Phase 1 – 2018
Phase 2 – 2019

High-conductivity carbon material (HCCM) for electrochemical applications

Semplastics
FOA: 1992
Announced Jan. 2020

Composite material for use in lithium ion (Li-ion) battery anodes

U. North Dakota
FOA: 2185
Award: 2021

Lignite-Derived Carbon Materials for Lithium-Ion Battery Anodes

PSI’s Innovative Process

PSI process produces a high conductivity carbon product for electrochemical applications with 20-30x higher value than that of the coal used as fuel
Coal to Carbon Nanomaterials

**University of Illinois**
- FOA: 1992
- Awarded – Sept. 2019
- High-value carbon nanomaterials and carbon sorbents

**Rice U**
- FOA: 1992
- Awarded – Sept. 2019
- High-quality graphene

**NETL - RIC**
- FWP-1022432
- Initiated 2018
- Coal-based Carbon Nanomaterials

**U. North Dakota**
- FOA: 1992
- Announced Jan. 2020
- Laboratory-Scale Coal-Derived Graphene
Coal to Conductive Inks

Expanding Viable High-value, High-growth Markets for Coal

• Inks infused with conductive materials
• Enables printing of electrically conductive surfaces
• Facilitates production of flexible, stretchable, potentially self-healing electrical circuits
• Conductive carbon materials produced from domestic coal enables lower production costs
Conductive Inks, 3D Printable Polymers, SiC Foam

**Conductive Inks**

**Minus 100**
SBIR Grant  
Phase 1 – 2018  
Phase 2 – 2019

New methods of manufacturing highly conductive ink pigments

**3-D Printable Polymers**

**H Quest Vanguard**
FOA: 1992  
Awarded – Sept. 2019

Carbon and graphitic materials for industrial electrode applications and advanced 3-D printable carbon polymer composites

**Silicon Carbide Foam**

**Touchstone Research Lab**
SBIR Grant  
Phase 1 – 2018  
Phase 2 – 2019

New silicon carbon (SiC) foam utilizing coal feedstock for s-CO2 turbine operation
NETL-RIC’s Coal to Products Research

NETL’s Research Innovation Center

Materials Discovery & Design

Market, Process, & Environmental Analysis

American Coal Database

- COLLECT AND CATALOG DATA:
  - Data Boundary
  - Interactive 3D Volume Rendering
  - Energy/Data Exchange

American Coal Database

U.S. DEPARTMENT OF ENERGY
Recent Accomplishments

NETL patent-pending technology converts coal into single-atom-thick carbon materials such as graphene.

NETL coal-derived additive enables stronger and more durable cement at reduced cost.

Coal-based nanomaterials manufactured at NETL are used to make computer memory devices.

NETL’s low-cost Coal to Graphene (C2G) technology was recognized with a prestigious R&D 100 Award.
Takeaways

• Exciting opportunities exist to create jobs, and produce high-value products, while reducing coal wastes
• New focus on building materials?
• Lab scale through pilot-scale development

Stakeholder involvement essential for transition of technologies to industry
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