

CARBON FORWARD

ADVANCED MARKETS FOR VALUE-ADDED PRODUCTS FROM COAL





CARBON FORWARD

Advanced Markets

For Value-Added Products from Coal

Executive Summary

October 2021

The National Coal Council (NCC) is a Federal Advisory Committee established under the authority of the U.S. Department of Energy. Individuals from a diverse set of backgrounds and organizations are appointed to serve on the NCC by the U.S. Secretary of Energy to provide advice and guidance on general policy matters relating to coal and the coal industry.

The findings and recommendations from this report reflect a consensus of the NCC membership, but do not necessarily represent the views of each NCC member individually or their respective organizations.

Access the full report on the NCC website via QR code



National Coal Council
1011 Bay Ridge Avenue #186
Annapolis, Maryland 21403
443-318-6052
www.NationalCoalCouncil.org
info@NCC1.org



CARBON FORWARD

Advanced Markets

For Value-Added Products from Coal

National Coal Council Leadership

NCC Chair – Randall Atkins, Ramaco Carbon

NCC Vice Chair – John Ward, National Coal Transportation Association

NCC CEO – Janet Gellici, National Coal Council

Report Chair

Rodney Andrews

Center for Applied Energy Research (CAER), University of Kentucky

Report Chapter Leads

Rodney Andrews, University of Kentucky

John Duddy, HTI

Janet Gellici, National Coal Council

Kim Johnson, Gen2, LLC

Lee Meyers, Carbon Fuels

George Skoptsov, H-Quest Vanguard

Executive Editor

Janet Gellici, National Coal Council

Department of Energy – NCC Deputy Designated Federal Officers

Thomas Sarkus, National Energy Technology Laboratory

Joseph Giove, U.S. Department of Energy

Library of Congress Control Number: 2021918824



Carbon Forward
Advanced Markets for Value-Added Products from Coal
Carbon Forward Report Committee

REPORT CHAIR: **Rodney Andrews**, Director

Center for Applied Energy Research, University of Kentucky

NCC STAFF: **Janet Gellici**, CEO, National Coal Council

WORKING GROUP:

Charles Atkins, Director R&D, Ramaco Carbon iPark

Carl Bauer, School of Energy Resources, University of Wyoming

Wendy Beach, Director of Operations & Business Development, Synfuels America

Donna Castro, CEO & Partner, PMO Virginia

Dan Connell, Senior Vice President Strategy, CONSOL Energy, Inc.

Don Cotchen, Vice President Sales, Industrial Info Resources

John Duddy, Vice President Coal Technology, HTI

Bill Easter, CEO, Semplastics EHC, LLC

David Eaton, Research Program Manager, CAER – University of Kentucky

Danny Gray, P.E., Executive VP – Strategy & Business Operations, Green Cement

Tom Gray, P.E., Manager-Mining & Mineral Resources, Tetra Tech Inc.

Alan Hill, C6 Firm (J.A. Hill Group, LLC)

Charles Hill, Director of Innovation, Ramaco Carbon

Richard Horner, Director Special Projects & Emerging Technologies

School of Energy Resources, University of Wyoming

Curt D. Horvath, Vice President Research, Design & Deployment

New Steel International

Kim Johnson, Managing Partner, Gen2LLC

Mike Jones, Ph.D., President, MLJ Consulting LLC (Lignite Energy Council)

Holly Krutka, Executive Director, University of Wyoming School of Energy Resources

Wenping Ma, Senior Engineer, CAER – University of Kentucky

Howard McClintic, Executive Director, CTC Foundation

Lee Meyer Esq., Managing Director, Carbon Fuels

Dr. Andre Moreira, CEO, Novihum Technologies GmbH

Jerry Oliver, Consultant, Koch Methanol

Rudy Olson, General Manager & Chief Technology Officer, CFOAM LLC

Fred Palmer, President, New Era Carbon

John Schultes, CEO & Founder, New Steel International

Connie Senior, Executive Editor-in-Chief, Clean Energy Journal

George Skoptsov, CEO, H Quest Vanguard

Judd Swift, President & CEO, Synfuels America

Stephen Truncate, Synfuels America

Rod Vera, Technologies International Corporation

Matthew Weisenberger, Associate Director, CAER – University of Kentucky

REPORT REVIEWERS:

Dick Bajura, West Virginia University
Rick Boyd, Dominion Energy
Dan Connell, CONSOL Energy
Ron Eller, Tinuum
Clark Harrison, Development & Diligence LLC
Dennis James, Dennis James Consulting LLC



October 23, 2021

The Honorable Jennifer Granholm
U.S. Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Madame Secretary:

On behalf of the members of the National Coal Council (NCC), we are pleased to submit to you the report “CARBON FORWARD: Advanced Markets for Value-Added Products from Coal.” The report’s primary focus is on assessing opportunities to enlist advanced manufacturing to enhance the use of U.S. coal in new and expanded carbon product markets. In the report we:

- Provide details on how coal-derived carbon products can support priorities of the Biden Administration for job creation, economic revitalization, environmental stewardship, infrastructure improvement and supply chain resilience.
- Highlight the various applications of carbon products for the aerospace, agricultural, automotive, consumer goods, construction, defense, energy, environmental and medical sectors.
- Detail the many benefits of coal-derived carbon products compared with conventional products, including improved product quality and performance, improved economics, enhanced environmental stewardship and enhanced national security.
- Describe how advanced manufacturing techniques will accelerate the economic value and commercialization of carbon products, as well as how coal-derived carbon products can support the deployment of advanced manufacturing in the U.S.

As we learn more about the complex molecular composition of coal, we come to appreciate the valuable role it can and must play in meeting our economic, environmental and national security goals. Other countries are using carbon products and materials produced from coal to advance their strategic goals. We need a national strategic objective in support of coal-derived products to ensure our nation can realize the full potential these products offer.

The recommendations of the National Coal Council to advance deployment and commercialization of coal-derived carbon products are organized to align with the Biden Administration’s priorities:

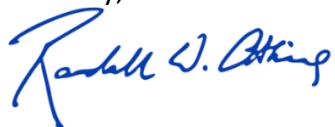
- **Job Creation** – High-value carbon product markets have significant employment and job creation potential. The U.S. Department of Energy’s own assessment indicates potential employment by 2050 of 280,000-480,000 in jobs associated with carbon product manufacturing. Deploying coal-to-products industries in distressed coal communities can provide good jobs in those regions targeted by the White House Interagency Working Group.

- **Economic Revitalization** – High-value carbon product markets have significant economic growth and cost-savings potential. These coal-derived technologies will fuel next generation carbon industries which, by DOE’s own assessment, will have a global market of more than \$96 billion by 2023 and a compound annual growth rate (CAGR) of 9.2%.
- **Environmental Stewardship** – High-value carbon products can support U.S. efforts to electrify the transportation fleet, reduce air emissions, provide clean drinking water, decrease energy consumption, sequester CO₂ and advance a hydrogen economy.
- **Infrastructure Improvement** – The Biden Administration’s infrastructure investment plans require basic commodities and construction materials that can be produced from coal at less cost, with enhanced technical performance, extended use life and environmental advantages vis-à-vis traditional products.
- **Supply Chain Resilience** – Domestically sourced and produced high-value carbon products can shore up vulnerable supply chains and reduce U.S. dependence on foreign sources for critical materials. Coal and coal ash are valuable sources for rare earth elements and critical minerals vital to production of electric vehicle and energy storage batteries, electronics, medical products, consumer goods and other strategic materials.

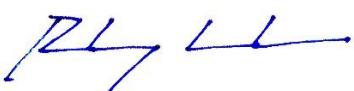
Coal-derived carbon products have a vital role to play in our nation’s future. Utilizing coal in these new and emerging markets can help the Administration achieve its priority objectives. The recommended policy and business approaches detailed in NCC’s CARBON FORWARD report provide a roadmap of assertive initiatives that acknowledge the value of our nation’s abundant, economic and versatile coal resources.

Thank you for the opportunity to prepare this report. The Council stands ready to address any questions you may have regarding its findings and recommendations.

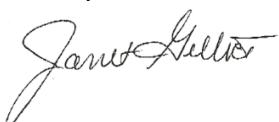
Sincerely,



Randall Atkins, National Coal Council Chair 2020-2021



Rodney Andrews, NCC Carbon Forward Report Chair



Janet Gellicci, National Coal Council CEO



Report Request Letter from Secretary Brouillette



The Secretary of Energy

Washington, D.C. 20585

September 22, 2020

Mr. Danny Gray, Chairman
National Coal Council, Inc.
1101 Pennsylvania Avenue, NW, Suite 300
Washington, DC 20004

Dear Chairman Gray:

I am writing today to request the National Coal Council (NCC) develop a white paper assessing opportunities to enlist advanced manufacturing techniques to enhance the use of U.S. coal beyond the power generation, steel making, and cement manufacturing markets.

The white paper should focus on new and expanded markets for “coal to products” and develop a roadmap of policies and approaches that would support research, development, and deployment (RD&D) of carbon-based products.

The white paper should provide an assessment of Federal and State policies, research and development investment options, and stakeholder partnership opportunities to advance these alternative markets for coal. Because advanced manufacturing techniques would be crucial to commercializing carbon-based products in the United States, advanced manufacturing techniques should feature prominently in the white paper.

Key questions to be addressed include:

- What existing or prospective Federal and State policies would support alternative markets for coal?
- What RD&D investments are needed to support alternative markets for coal?
- What opportunities should be pursued among stakeholder groups in this sector to support alternative markets for coal?
- What strategic U.S. national interests are impacted by the development of coal-to-products and advanced materials?

I ask that the white paper be completed no later than May 30, 2021.

Upon receiving this request and establishing your internal working groups, please advise me of your schedule for completing the white paper. The Department looks forward to working with you in this effort.

Sincerely,

A handwritten signature in black ink that reads "Dan Brouillette".

Dan Brouillette



Carbon Forward

Advanced Markets for Value-Added Products from Coal

Table of Contents

Executive Summary

Chapter I. The Coal to Products Opportunity

- a. The Compelling Case for Value-Added Products from Coal
- b. Coal-to-Products Benefits of Specific Applications

Chapter II. Production Pathways for Coal-Derived Products

- a. Conventional Production/Manufacturing Pathways
- b. Advanced Manufacturing Pathways

Chapter III. Coal-Derived Products and Markets

- a. Coal to Gas – Acetylene, Syngas, Synthetic Natural Gas, Hydrogen & Ammonia
- b. Coal to Liquids – Fuels and Chemicals
- c. Coal to Solid Carbon Products
- d. Building and Construction Materials
- e. Rare Earth Elements and Critical Minerals
- f. Agricultural Products
- g. Status of Coal to Products Technologies Development and Deployment

Chapter IV. Approaches to Coal-to-Products Commercialization

- a. From Lab to Fab(rication): The RD&D Continuum to Market Deployment
- b. Demonstration Projects: Value, Need and Funding
- c. U.S. and State Government Guaranteed Purchase Agreements: Value and Need
- d. Advanced Manufacturing for Coal-to-Products: Enablers and Opportunities
- e. Model Initiatives in Advanced Manufacturing Deployment and Funding

Chapter V. Coal-Derived Markets Support the Biden Administration's Priorities

- a. How coal-derived products can support the Biden Administration's job creation efforts.
- b. How coal-derived products can support the Biden Administration's economic recovery efforts.
- c. How coal-derived products can support the Biden Administration's climate and environmental objectives.
- d. How coal-derived products can support the Biden Administration's infrastructure improvement initiatives.
- e. How coal-derived products can support the Biden Administration's efforts to shore up our nation's vital supply chains.

Chapter VI. Recommendations & Key Questions Addressed

Guiding Principles

Key Recommendations

Key Questions Addressed:

Federal & State Policies

- a. Initiatives to Advance RD&D
- b. Initiatives to Minimize Cost and Risk
- c. Initiatives to Support Economic Revitalization and Infrastructure Modernization
- d. Initiatives to Reduce Regulatory Burden
- e. Initiatives to Support Workforce Development and Public Acceptance

Research, Development and Deployment Investments

- a. Research
- b. Development
- c. Deployment

Partnership Opportunities

- a. Partnership Models: Overview of Current NETL-Stakeholder Partnerships
- b. NETL Partnership Opportunities
- c. Partnership Example: Carbon Ore, Rare Earth and Critical Minerals Initiative
- d. Interagency and Government-wide Opportunities

U.S. Strategic National Interests

Chapter VII. Roadmap

Appendices

- A. Coal-to-Products Technology Compendium
- B. Current U.S. Department of Energy Coal-to-Products Research, Development & Deployment Initiatives
- C. Current Pathways for Production & Manufacturing of Coal-Derived Products
- D. NCC Overview – 1984|2021
- E. NCC Membership Roster



Carbon Forward

Advanced Markets for Value-Added Products from Coal

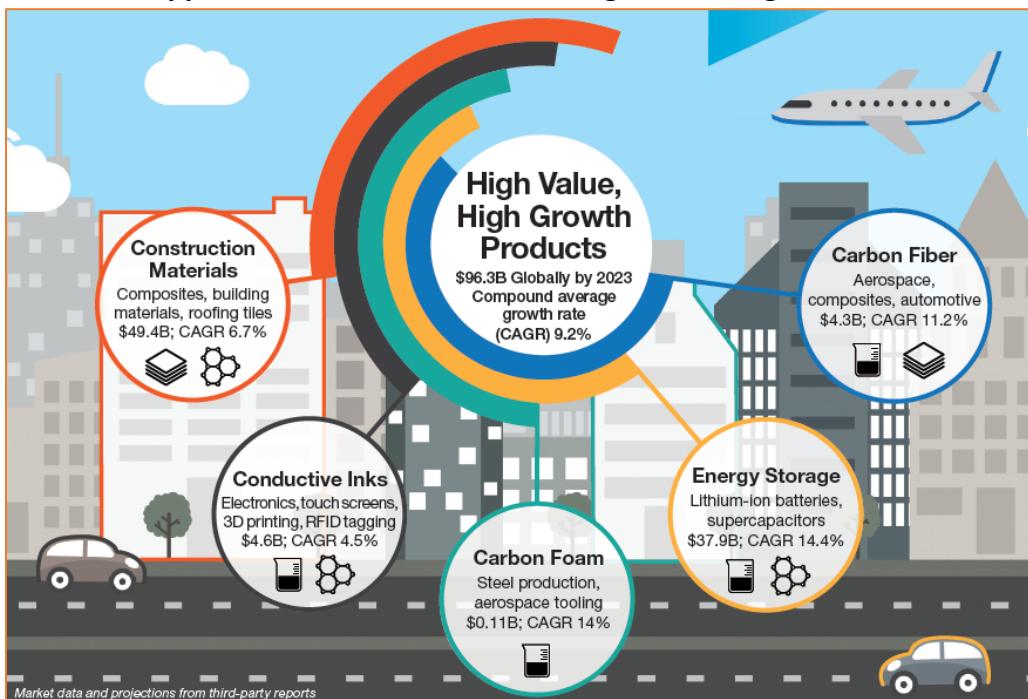
Executive Summary

The Value and Opportunity of Coal to Carbon Products

In the 20th century, coal achieved prominence in the production of electricity generation and steel, helping to establish the United States as a global industrial powerhouse. Coal's role in the 21st century new carbon age promises to be equally significant. Our nation's abundant coal resources can be used as an economic feedstock in the production of a variety of critical goods and materials.

Coal-derived products have valuable applications in the aerospace, agricultural, automotive, consumer goods, construction, defense, energy, environmental and medical sectors. These high-growth market sectors, fueled by strides in advanced manufacturing, offer the U.S. opportunities to establish its role as a global leader in next-generation industries.

Product & Application Market Potential of High-Value/High-Growth Products



National Energy Technology Laboratory

Coal's complex chemical structure enables it to be used to manufacture:

- asphalt and ammonia
- batteries and bricks
- concrete and ceramics
- diesel fuel and 3D printing ink
- electronics and electrodes
- fertilizers and facades
- golf balls and graphene
- hydrogen and humic acid
- inks and insulation
- magnets and methanol
- pencils and pharmaceuticals
- sensors and solar panels
- tennis rackets and textiles
- wind turbine blades and water filters

Further research into the molecular genome of coal holds promise for identifying even more ways it might be used as a critical materials resource. Coal is not a monolithic material; its complex and unique chemical properties are just beginning to be identified and valued for their potential utility in production of value-added carbon products.

Many coal-derived products offer benefits vis-à-vis traditionally manufactured products:

- ***Improved Product Quality and Performance*** – stronger, more durable, lighter weight, corrosion and fire resistance, greater energy storage capacity
- ***Improved Economics*** – reduced manufacturing complexity = reduced costs, domestically abundant and affordable coal resource base, utilization of existing infrastructure
- ***Enhanced Environmental Stewardship*** – lighter weight, more energy efficient production, shorter supply chains reduce emissions, carbon dioxide (CO₂) sequestration potential, reduced water consumption, hydrogen production potential
- ***Enhanced National Security*** – improved supply chain resilience through use of domestic resources and diversified feedstock sources, reduced dependence on imports

Advancement of coal to carbon products markets offers the additional benefit of creating a significant number of well-paying jobs. The U.S. Department of Energy's (DOE) own assessment indicates the potential for 280,000 to 480,000 manufacturing jobs in various carbon product industries. Many of these jobs can be created in economically distressed communities impacted by the decline in U.S. coal production and coal power generation.

**Potential Demand for New Coal Production & Employment
Associated with Markets for Carbon Products**

Carbon Product	Potential U.S. Coal Industry Requirements - 2050*		U.S. Product Value -2050 (Million \$) *	Employment-2050 (Mfg.)*
	Coal Production (mmt)*	Coal Mining Employment*		
Activated Carbon	22	2,641	15,979	32,437
Carbon Anodes (incl. Aluminum, Li-Ion Battery Anodes)	35	4,257	31,289	63,476
Carbon Black	14.1	1,692	5,077	10,306
Graphite Electrodes/Needle Coke	12.5	1,502	41,315	83,869
Carbon Fiber (incl. CFRP, C-C composites, cement)	47.6	5,713	24,701	50,127
Carbon Nanomaterials (incl. cement)	12.1	1,457	14,125	28,300
Conductive Inks	0.001	1	264	500
Roofing Tile	2	243	7,192	14,500
Aggregate**	100+	15,000+	TBD	100,000+
Foam - Building Mat**	100+	15,000+	TBD	100,000+
Total Carbon Products	145 to 345+	17,500 to 47,500+	139,000 +	280,000 to 480,000+

* Values reported in 2050 represent a high coal penetration scenario in which carbon-based products made from coal penetrate 80 percent of the overall product market. Additionally, several products (e.g., anodes/electrodes, CF & graphene) represent high demand growth scenarios.
 ** Data from project estimates with technology developers for large commodity markets

U.S. Department of Energy/Office of Fossil Energy

Finally, in considering the value associated with coal-derived carbon products, it is important to distinguish between “carbon” used to produce value-added products and the “carbon” referred to in carbon dioxide - CO₂. Carbon used for production of carbon-based products should not be confused with the carbon in CO₂ emissions. In fact, because many products made from or containing carbon have superior strength, weigh less and require less energy to produce than traditional materials, carbon-based products may have a substantially reduced environmental impact and contribute to efforts to reduce CO₂.

Coal-to-Products Support Biden Administration Priorities

The many benefits associated with deployment of coal-derived carbon products align with priorities established by the Biden Administration. Since taking office in January 2021, the Administration has advanced numerous initiatives supporting job creation, economic revitalization, environmental stewardship, infrastructure improvements and supply chain resilience. Chapter V of this report details how coal-derived products support the Administration’s efforts in each of these areas. In summary:

Job Creation

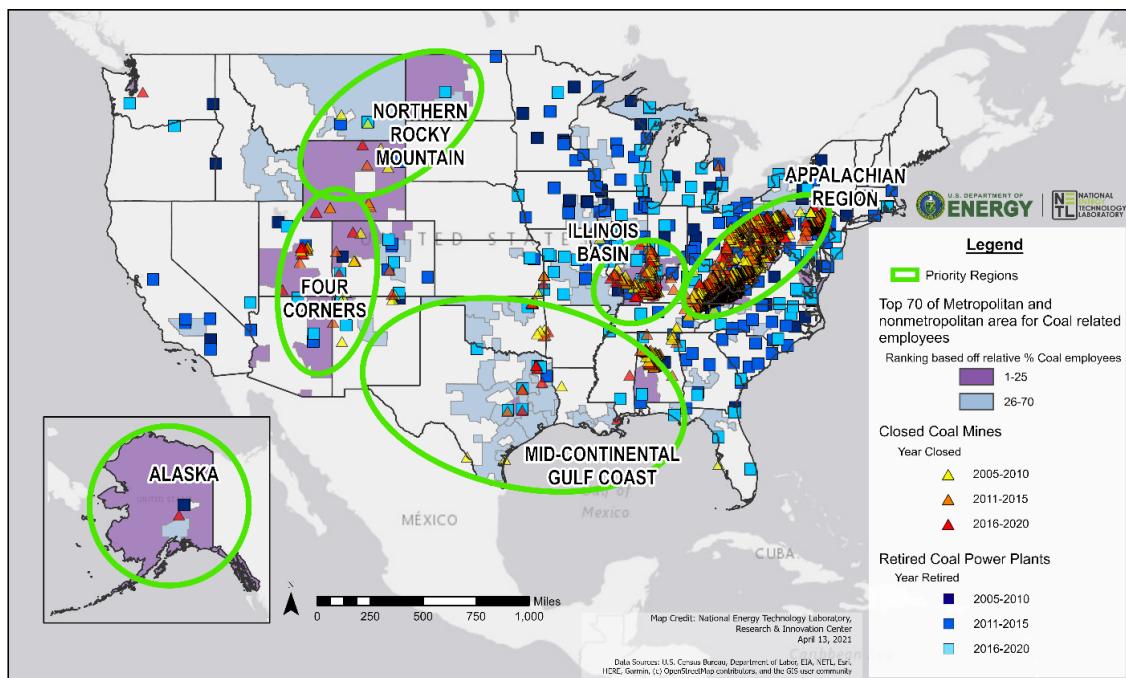
The Administration's American Jobs Plan seeks to revitalize manufacturing and train Americans for the jobs of the future. The Plan also highlights the need to build next-generation industries in distressed communities, especially those impacted by the recent energy transition.

Established by a Presidential Executive Order, the White House Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization has identified immediately challenged coal communities, targeting them as key locations for Federal investment for job creation, for initiatives to strengthen manufacturing supply chains for critical goods and for remediation/redevelopment of brownfield sites into new hubs of economic growth.

Coal Mining & Power Plant Impacted Areas

White House Interagency Working Group

on Coal & Power Plant Communities & Economic Revitalization



It is precisely these communities in which jobs can be readily created through deployment of coal-to-products manufacturing. Investment for research, development and demonstration (RD&D) and deployment of commercial-scale projects using advanced manufacturing technologies to produce coal-derived high-value carbon products will provide opportunities to train workers for careers in growth industries with attractive salary and benefit potential. It will also afford these workers an opportunity to remain in their established local communities.

Economic Revitalization

The American Jobs Plan calls for investment in R&D and technologies of the future, highlighting the need for public investment in breakthrough technologies to maintain the nation's economic edge in today's global economy. Enhanced investments in researchers, laboratories and universities, in partnership with the private sector, will support the carbon-based industries of the future. Recognizing the government's buying power and ability to be a first-mover in markets, the Jobs Plan also calls for jumpstarting clean energy manufacturing through Federal procurement.

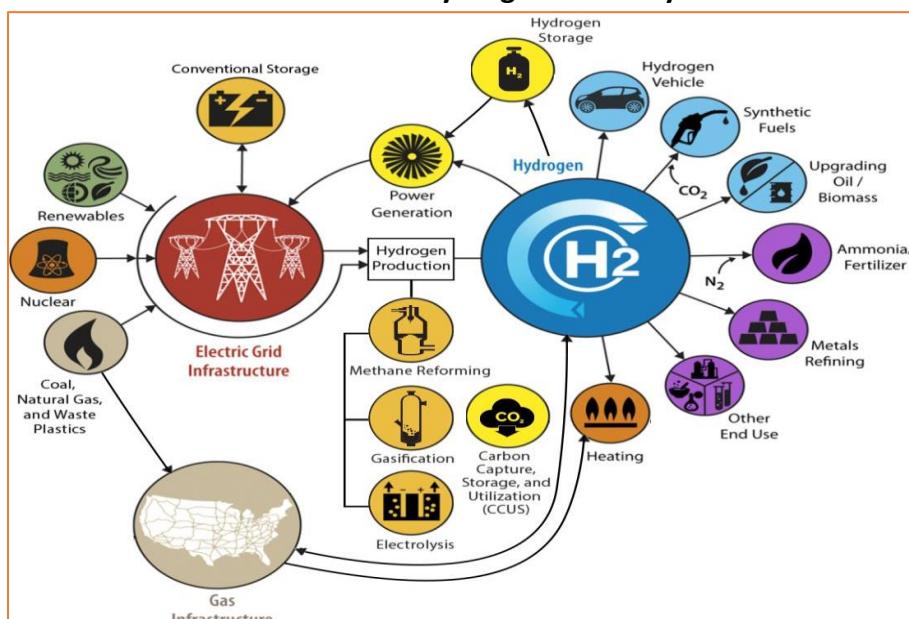
Emerging high-value carbon product markets provide materials critical to clean energy industry sectors, including those for electric vehicles and renewable energy, and have significant economic growth potential. The National Energy Technology Laboratory (NETL) projects that these products will have a global market value of over \$96 billion by 2023 and a Compound Annual Growth Rate (CAGR) of 9.2%.

Environmental Stewardship

As noted earlier, coal-derived carbon products offer numerous environmental benefits. These products support the Administration's stated objectives to deliver clean drinking water, electrify the automotive industry, reduce energy consumption and emissions in both the manufacturing process and in end-use applications, and sequester CO₂.

Additionally, the Administration's initiatives to advance a "Hydrogen Economy" in which hydrogen is used for power generation, heating, transportation, fertilizer production and energy storage, can also be supported by coal. Gasification of coal, which is undertaken to produce liquid fuels, chemicals and synthetic natural gas (SNG), is one production pathway used to make hydrogen. Large centralized coal gasification facilities, equipped with carbon capture, utilization and storage (CCUS) technology, can play a major role in meeting hydrogen production needs.

Vision of the Hydrogen Economy



U.S. Department of Energy

Infrastructure Improvements

The Administration's Jobs Plan calls for investments to be made in both the construction and repair of U.S. infrastructure, including roads, bridges, rail, ports, airports and transit systems. Many of the basic commodities and construction materials needed to shore up our nation's infrastructure can be produced from coal at less cost, with enhanced technical performance, extended use life and environmental advantages vis-à-vis traditional materials.

The Jobs Plan also identifies the need to "reenergize America's power infrastructure," by creating a more resilient grid and "incentivizing more efficient use of existing infrastructure." Co-locating coal-to-products advanced manufacturing facilities with existing coal mining, transportation and power station infrastructure will provide a more streamlined and cost-effective opportunity to deploy new manufacturing plants while simultaneously incentivizing mine, transport and power station owners to invest in efficiency upgrades to their operations.

Supply Chain Resilience

In an Executive Order on “America’s Supply Chains,” President Biden directed the U.S. government undertake a review of U.S. supply chains with the aim of identifying risks and vulnerabilities. DOE was specifically tasked with identifying risks in the supply chain for high-capacity batteries that could be used for electric vehicles and energy storage. In response, DOE recommended establishing government policies incentivizing every stage of the U.S. battery supply chain, including securing a domestic supply of critical materials for high-capacity lithium-ion batteries. Many of the rare earth elements (REEs) and critical minerals (CMs), including carbon materials, necessary for the production of these batteries can be sourced from coal, coal ash and coal residuals. Supporting RD&D to recover REEs and CMs from coal will enable the U.S. to reduce its dependence on foreign sources for these and other materials that are critical components of the automotive, aerospace, defense, electronics and consumer goods industries.

The U.S. coal supply chain is well established and wide-ranging. Advanced manufacturing facilities for coal-derived products would benefit from utilization of established supply chains for coal production, transport (rail, port, truck) and on-site storage.

It is worth noting, that other nations are using coal-derived products to enhance their strategic supply chain resilience. U.S. supply chain resilience will be enhanced by ensuring access to all domestic coal resources, including run-of-mine coal, coal ash and coal tailings. Restricting or extending preferential treatment for RD&D funding for any of these resources, e.g., waste coal, may limit available resources and reduce supply chain resilience for critical materials.

The U.S. can benefit greatly and in many ways from efforts to support the deployment of coal-derived carbon products. Advanced manufacturing will be a critical component in the rapid deployment of coal-to-products technologies.

Pathways to Commercialization of Coal to Carbon Products

Production of coal-derived carbon products relies on both conventional and advanced manufacturing techniques. Conventional manufacturing refers to the process of converting raw materials into a finished, saleable product by manual and/or mechanized transformational techniques. Primary among these conventional processes are beneficiation, gasification, calcination, pyrolysis, injection molding and manual carbon fiber layup. With an enhanced focus on initiatives to address carbon management objectives, conventional pathways will continue to play a vital role in the production and manufacturing of coal-derived products.

Advanced manufacturing employs innovative technology to improve products and/or manufacturing processes, providing tools that can drive the rapid transfer of science and technology into manufacturing products and processes. Advanced manufacturing is critical to increasing U.S. competitiveness and facilitating technology transition in many industry sectors. The use of advanced techniques and equipment, such as automation, computation, digitization, artificial intelligence, sensing and networking, will provide the U.S. with the ability to achieve its economic, environmental and national security objectives.

Using coal to produce carbon products is a paradigm shift and advanced manufacturing will be a critical component in the rapid deployment of coal-to-products technologies. While commercial deployment of products from coal will benefit from utilizing advanced manufacturing techniques, it will also contribute to the development of both advanced manufacturing materials and advanced manufacturing processes.

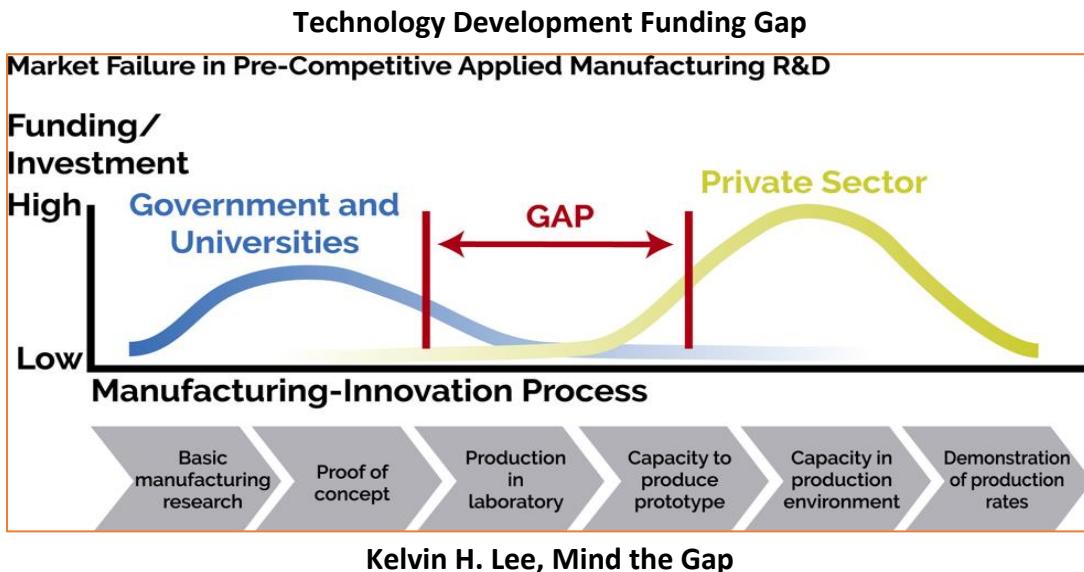
Coal-derived manufacturing materials that have a vital role in facilitating the development of advanced manufacturing include critical materials/minerals, wide bandgap semiconductors for power electronics, materials for harsh service conditions, advanced materials manufacturing and composite materials.

The technologies used to make materials and products from coal will require advanced manufacturing processes. These include: 1) computer technologies and high-performance computing for modeling, simulation and analysis, 2) rapid prototyping (additive manufacturing), advanced robotics and other intelligent production systems, 3) automation and control systems to monitor processes, and 4) agility to custom manufacture products and to manufacture at high or low volume. Moreover, and most important, is the capability to be sustainable, utilizing environmentally sound processes and technologies.

Examples of advanced manufacturing processes and techniques being used to produce value-added products from coal detailed in this report include carbon foam, single batch composites and thermo-chemical coal refining. Many other examples exist.

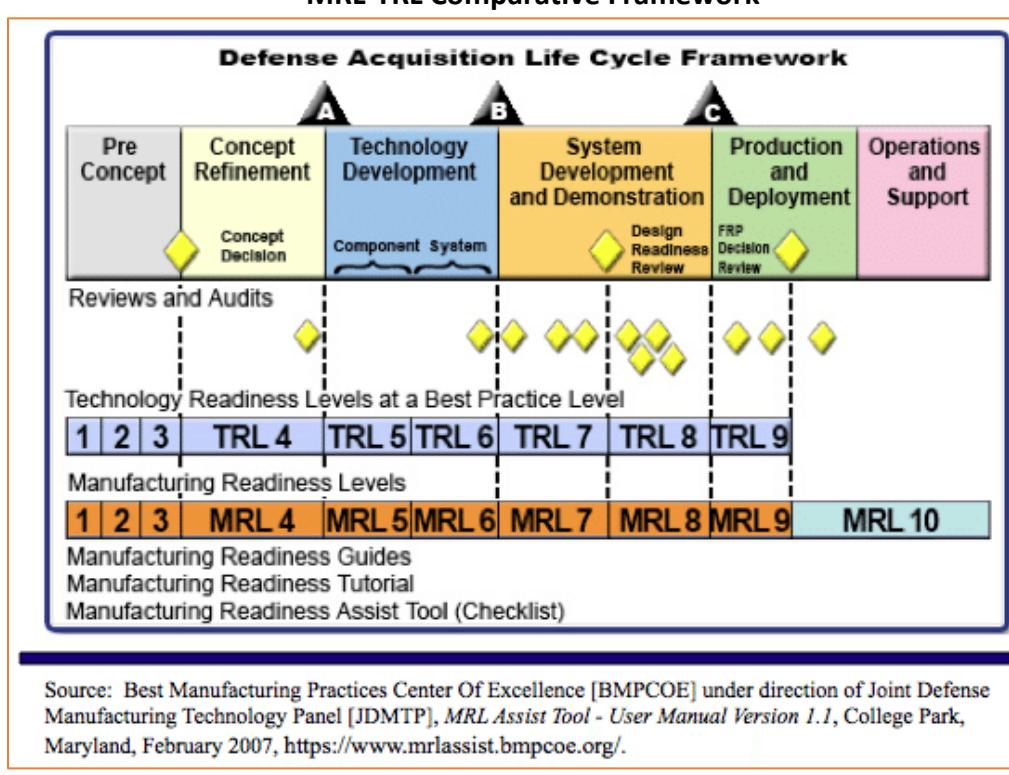
Commercialization of Coal to Carbon Products

Successful deployment of technologies for production of value-added products from coal will require addressing the gap between basic laboratory R&D typically conducted by government and universities with some support from the private sector, and the commercial demonstration of these technologies largely funded by the private sector. The major time delay and primary obstacle is a gap in the availability of funding through the so-called “development death valley.” Accelerating technology innovation and deployment for value-added products from coal needs to address this gap.



Numerous initiatives can be undertaken to bridge this commercialization gap:

- DOE's Technology Readiness Levels (TRLs) and the U.S. Department of Defense's (DOD) Manufacturing Readiness Levels (MRLs) can be useful tools in developing and commercially deploying technologies, especially when used in conjunction with each other.



- Intra-governmental collaboration between departments, such as DOE and DOD, could help enhance market development for advanced carbon materials such as carbon fibers, carbon foam and graphene.
- In addition to the upstream RD&D being funded by DOE/NETL that is focused on developing products and materials from coal and associated manufacturing processes, there is a need for downstream RD&D focused on applications and end-use market development.
- It is very common for technology development to stall at the demonstration stage of technology maturity. Even very promising new technologies, especially complex and capital-intensive technologies, remain un-deployed due to the lack of an effective demonstration. The cost and risk of demonstration projects deter private investments, especially for First-of-a-Kind (FOAK) technologies. The Federal government has often shied away from technology demonstration, even when its R&D investments have brought technologies to the point of demonstration readiness. A well-funded demonstration program for various coal-derived products could help overcome technical and cost barriers.
- Lack of experienced large-scale project managers has also been noted as a challenge to the success of commercial project demonstrations. To enhance prospects for success, demonstration projects need to be managed by senior industry personnel experienced in oversight, finance and management of large-scale projects.
- The Federal government is the single largest consumer in the world, spending more than \$550 billion on products and services each year. Both the Federal government and state governments have established procurement and incentives programs in place to ensure cost competitiveness, fairness and support for policy directives, e.g., the Federal Environmentally Preferable Program and DOD's Defense Production Act, Title III. Procurement programs could be enacted for Federal and state procurement for products and minerals derived from U.S. coal.
- Programs and partnerships supporting advanced manufacturing could be pursued to enhance commercialization of coal-to-products. Prospective models and partnership opportunities include the National Science Foundation's Advanced Manufacturing program, the National Institute of Standards and Technology's Office of Advanced Manufacturing, the Advanced Materials Future Preparedness Taskforce, the Additive Manufacturing Coalition and the European Union's Horizon 2020 initiative.
- The various initiatives underway in the State of Wyoming to create a "Carbon Valley," similar in concept to "Silicon Valley" in California, provide a model for other states and an opportunity for DOE to support and showcase the value of collaboration among industry, government and academia.

Recommendations & Roadmap for Coal to Products Deployment

The abundant coal resources located throughout the U.S. are a valuable and versatile asset that can be used as a raw material in the production of high-value products critical to our nation's economic, environmental and national security. The U.S. Department of Energy, in collaboration with other Executive Branch agencies, has a vital role to play in supporting the accelerated deployment of coal-to-products technologies. An interagency effort will more quickly and efficiently advance commercialization of these vital products.

A national strategic objective in support of coal-derived products is necessary for commercial deployment. A national RD&D effort must support a full range of technologies and markets. Our ability to understand the 'materials genome' of coal can provide insight into how to use coal as an important materials resource. Funding for fundamental science is crucial to realize the full potential of coal as a feedstock for new, non-traditional uses.

Federal and state governments can support and accelerate the commercialization of coal-derived carbon markets through policies and investments in research, development and deployment, as well as through partnerships with industry, academia and stakeholder groups. Support for common user facilities, easing of cost-share restrictions that effectively exclude viable participants and availability/extension of a variety of R&D tax credits for coal-derived carbon products are among the potential initiatives that might be employed.

Initiatives are needed to minimize costs and risks associated with technology development. Grants, loan guarantees, floor pricing, long-term contracting, Federal procurement programs, "Buy American" efforts and Federal/state tax incentives could enhance opportunities for technology developers and investors. Expedited permitting for coal to products facilities and other efforts to reduce similar regulatory burdens would provide additional incentives.

Transitioning from laboratory to small and large pilot projects is often a stumbling block for many technologies. The step from laboratory scale research to deployable technology is often underfunded. Investments that allow flexible, multi-user facilities to be used for development across a wide range of scales at the pre-competitive stage help reduce risk, encourage collaboration and allow for rapid results while maximizing return on Federal investments.

Technology Commercialization Continuum



U.S. Government Accountability Office

Federal cost sharing or loan guarantees directed at reducing the risk of deployment of FOAK plants could accelerate commercialization of coal-derived products significantly. Federal government support for demonstration projects would help bridge the “Development Valley of Death” between research and commercial deployment. Government support for demonstration projects would also provide a level of reassurance for prospective financial investors.

Public acceptance and a trained workforce will be essential to successfully deploy coal to products and advanced manufacturing initiatives. Federal and state-supported education and training programs are needed in these early stages of carbon age industry commercialization. Complementing workforce development initiatives with visible government encouragement for these industry sectors will advance public acceptance of coal-derived carbon markets.

The recommendations included in this report have been organized to coincide with the Biden Administration’s priority objectives to enhance job creation, economic revitalization, environmental stewardship, infrastructure improvements and supply chain resilience. In pursuit of these objectives, the National Coal Council recommends undertaking near-term initiatives within the next five years to lay a foundation for enhancing the use and deployment of critical coal-derived products and materials, enlisting advanced manufacturing techniques. Longer-term initiatives over the ensuing five to ten years will help ensure and accelerate the commercialization of coal-to-products and advanced manufacturing technologies.

These near-term and longer-term initiatives include policies, business approaches and partnership opportunities that will require the participation of Federal and state governments, academia, non-profit organizations and industry. Working together, these entities can forge a path forward for markets and technologies for value-added products from coal that will enhance our nation’s economic, environmental and national security interests.

**Near-Term Initiatives (within the next 5 years)
to Deploy Coal-Derived Value-Added Products in Support of:**

Job Creation

- Locate coal-to-products development and advanced manufacturing facilities in regional hubs and economically distressed communities pursuant to \$20 billion referenced in the American Jobs Plan.
- Provide inter-agency support for the Department of Commerce-Economic Development Administration's efforts to prioritize investments in projects that encourage economic diversification, job creation, capital investment, workforce development and re-employment opportunities.
- Extend grants through the Appalachian Regional Commission's (ARC) programs for coal-to-products initiatives that support workforce development, entrepreneurship and industry clusters. Employ the ARC program as a model for other regionally based initiatives.
- Designate shuttered and operating coal mine/power plant sites as economic revitalization zones for next generation industries.
- Support the American Jobs in Energy Manufacturing Act of 2021 (Manchin/Stabenow) and efforts of the White House Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization.

Economic Revitalization

- Extend Federal funding to include pre-competitive programs across a wide range of coal-derived products.
- Identify and fund Federal/state common-user facilities to enable cost-effective partnerships for technology development and commercial deployment.
- Eliminate cost-share policies that limit participation in grant programs and exclude potential researchers.
- Expand Funding Opportunities beyond rare earth elements/critical minerals to encompass other coal-derived value-added products.
- Expand fundamental research detailing the "materials genome" of coal and how it might be used as a critical materials resource.
- Host DOE/NETL workshops and other stakeholder meetings to secure input from and facilitate collaboration among Federal/state governments, academia, coal-to-products technology developers and advanced manufacturing stakeholders.

Environmental Stewardship

- Acknowledge the energy-saving, emissions-reduction and other environmental benefits of coal-derived products, emphasizing the distinction between "carbon" dioxide emissions and "carbon" used to produce value-added products.
- Incentivize inclusion of coal-derived products with CO₂ sequestration and reduced energy consumption capability as a component of U.S. initiatives to reduce greenhouse gas emissions.
- Extend the 45Q tax credit to those coal-derived products that sequester CO₂.
- Establish Federal procurement guidelines for coal-derived products to enable them to qualify under the Environmental Protection Agency's Environmentally Preferable Purchasing Program.
- Establish "Buy American" incentives for green energy and clean drinking water projects utilizing coal-derived products.
- Support the use of coal-derived soil amendments that do not add toxins, heavy metals or carcinogenic compounds to the soil.

**Near-Term Initiatives (within the next 5 years)
to Deploy Coal-Derived Value-Added Products in Support of:**

Infrastructure Improvements

- Recognize the superior, high-performance benefits of coal-derived products and incentivize use of these products as a component of U.S. infrastructure improvement efforts.
- Establish “Buy American” incentives for infrastructure investments utilizing coal-derived products with enhanced durability and strength.
- Secure Defense Protection Act authority for DOE under Title III to issue grants, loans, loan guarantees and other economic incentives to address critical infrastructure vulnerabilities.

Supply Chain Resilience

- Incentivize the use of domestic, abundant U.S. coal resources to produce high-value critical materials, reducing our nation's dependence on foreign sources.
- Secure Defense Protection Act authority for DOE under Title III to issue grants, loans, loan guarantees and other economic incentives to enhance supplies of critical materials.
- Execute President Biden’s E.O. 14017 initiative to incentivize U.S. battery supply chain stakeholders, including coal-sourced rare earth elements and critical minerals essential for the production of electric vehicle and consumer goods batteries.
- Revitalize Section 48C Advanced Manufacturing Tax Credits and expand Section 1603 of the American Recovery and Reinvestment Tax Act (ARRTA) to support small manufacturers of batteries and associated materials suppliers.
- Extend the 48C Advanced Manufacturing Tax Credit program to include coal-derived product manufacturers.
- Utilize Department of Defense requirements for U.S. sourced materials.
- Support Congressional initiatives that promote domestic exploration, R&D and processing of critical minerals, including those derived from coal, coal ash and coal tailings, i.e., American Critical Minerals Independence Act of 2021 (H.R. 2637), the Securing America’s Critical Minerals Supply Act (H.R. 1599) and the Strategic Energy and Minerals Initiative Act of 2021 (S. 1537).
- Support initiatives within the U.S. Innovation and Competition Act (S. 1260) to establish a Directorate for Technology and Innovation within the National Science Foundation and to develop a strategy to establish a critical supply chain resiliency program.
- In response to the White House Report on Building Resilient Supply Chains, DOE should collaborate with the Departments of Commerce and Transportation to address supply chain challenges associated with food supply.
- Enhance supply chain resilience by ensuring access to all domestic coal resources, including run-of-mine coal, coal ash and coal tailings.

**Longer-Term Initiatives (within the next 5-10+ years)
to Deploy Coal-Derived Value-Added Products in Support of:**

Job Creation

- Deploy Federal and state workforce education and training programs geared to STEM-literate high school graduates and trained technologists with skills essential to both coal-to-products and advanced manufacturing.
- Employ DOE investigator grants and contracts to support training of undergraduate and graduate science/engineering students with skills needed for technology development.
- Expand the University Coal Research program to include topics in the areas of coal-to-products and advanced manufacturing.

Economic Revitalization

- Fund demonstration projects, managed by personnel experienced in administering large-scale projects, to help bridge the “Development Valley of Death.”
- Utilize Federal cost sharing and loan guarantees to help reduce the risk associated with deploying First-of-a-Kind plants.
- Offer Federal purchase agreements for coal-derived products, establishing appropriate guidelines, standards, certificates and validations to foster enhanced Federal procurement.
- Employ Federal and state tax credits to encourage private investment in new technologies.
- Extend the 48C Advanced Manufacturing Tax Credit program to include coal-derived product manufacturers to incentivize private sector investment.
- Consider employing Federal and/or state severance and use tax rebate programs for coal used in the manufacture of non-fuel products.
- Include coal-to-products manufacturing facilities within state high-tech incentive pools for economic development.
- Expedite Federal and state permitting of coal-derived product manufacturing facilities that support the Administration’s economic revitalization and job creation objectives.
- Fund research support beyond laboratory scale for adaptation of advanced manufacturing technologies for coal conversion.
- Establish a DOE program similar to the National Science Foundation’s Mid-scale Research Infrastructure program, focused on funding mid-scale capabilities to advance critical materials and coal-to-products.

Environmental Stewardship

- Utilize coal sourced from waste ponds/tailings when economically feasible and non-detrimental to end-product quality vis-a-vis use of run-of-the-mine coal.
- Pursue R&D related to utilization of coal for production of hydrogen as a carbon-free fuel for electricity generation and for vehicles.
- Pursue applications that combine coal feedstocks and renewable electricity to reduce CO₂ emissions from manufacturing and that can be deployed at the point of use, eliminating transportation costs and associated emissions.

**Longer-Term Initiatives (within the next 5-10+ years)
to Deploy Coal-Derived Value-Added Products in Support of:**

Infrastructure Improvements

- Pursue technology and cost-reduction R&D initiatives supporting the deployment of high-performance coal-derived asphalt.

Supply Chain Resilience

- Establish floor pricing on rare earth elements and critical minerals to incentivize private sector investment in materials critical to U.S. national security and supply chain resilience.
- Employ long-term contracting for U.S. materials to facilitate market price stability.
- Establish Federal Executive Agency Offices to monitor domestic industrial capacity and deployment of advanced manufacturing facilities to support modernization of manufacturing supply chains for critical goods.
- Locate coal-to-products technology and production/manufacturing facilities close to abundant coal supplies and affordable power generation plants. Shorter supply chains are less vulnerable to disruption.



In the fall of 1984, Secretary of Energy Don Hodel announced the establishment of the National Coal Council (NCC). In creating the NCC, Secretary Hodel noted that “The Reagan Administration believes the time has come to give coal – our most abundant fossil fuel – the same voice within the federal government that has existed for petroleum for nearly four decades.”

The Council was tasked to assist government and industry in determining ways to improve cooperation in areas of coal research, production, transportation, marketing and use. On that day in 1984, the Secretary named 23 individuals to serve on the Council, noting that these initial appointments indicate that “the Department intends to have a diverse spectrum of the highest caliber of individuals who are committed to improving the role coal can play in both our Nation’s and the world’s energy future.”

Throughout its 37-year history, the NCC has maintained its focus on providing guidance to the U.S. Secretary of Energy on various aspects of the coal industry, including coal policy, technology and markets. NCC has retained its original charge to represent a diversity of perspectives through its varied membership and continues to welcome members with extensive experience and expertise related to coal.

The NCC serves as an advisory group to the Secretary of Energy chartered under the Federal Advisory Committee Act (FACA). The NCC is incorporated as a 501c6 non-profit organization in the State of Virginia. Serving as an umbrella organization, NCC, Inc. manages the business aspects of running the Council.

The Council’s activities include providing the Secretary with advice on:

- Federal policies that directly or indirectly affect the production, marketing and use of coal;
- Plans, priorities and strategies to address more effectively the technological, regulatory and social impact of issues relating to coal production and use;
- The appropriate balance between various elements of Federal coal-related programs;
- Scientific and engineering aspects of coal technologies, including coal conversion, utilization or environmental control concepts; and
- The progress of coal research and development.

The principal activity of the NCC is to prepare reports for the Secretary of Energy. Over the past 37 years, the NCC has prepared over 40 report for the Secretary. All NCC reports are publicly available on the NCC, Inc. website at www.NationalCoalCouncil.org.



NCC Members June 2021

Thomas H. Adams

American Coal Ash Association

Barbara Farmer-Altizer

Metallurgical Coal Producers Association

Donna D. Anderson

Babcock Power Services Inc.

Ato Andoh

GCS Fibers LLC

Rodney Andrews

*Center for Applied Energy Research "CAER"
University of Kentucky*

Shannon Angielski

Carbon Utilization Research Council

Duane Ankney

State of Montana

Randall Atkins

Ramaco Carbon

Richard L. Axelbaum

*Consortium for Clean Coal
Washington University (St. Louis)*

Richard Bajura

*Nat'l Research Center for Coal & Energy
West Virginia University*

John Bauer

Great River Energy

Jason Begger

Wyoming Infrastructure Authority

Dr. Steven A. Benson,

Microbeam Technologies Incorporated

Jacqueline F. Bird

JFBird Enterprises

Michelle Bloodworth

America's Power

Wade Boeshans

BNI Energy Inc.

Jason Bohrer

Lignite Energy Council

Rick Boyd

Dominion Energy

Joseph Boylan

Morgan Advanced Materials

Lisa J. N. Bradley, PhD, DABT

Haley & Aldrich

James 'Jimmy' Brock

CONSOL Energy Inc.

Dr. Alfred 'Buz' Brown

ION Clean Energy, Inc.

Charles Bullinger

Eagle Creek Consulting

Wanda I. Burget

Accord Resources Solutions

Keith Casey

Emerson

John Cassady
Wabash Valley Power

Randel D. Christmann
North Dakota Public Service Commission

Steve L. Clark
Systems International Incorporated

Kipp Coddington
*School of Energy Resources
University of Wyoming*

Donnie Colston
International Brotherhood of Electrical Workers

Stephen Conway
Wood PLC

Donald Anthony Cotchen
Industrial Info Resources, Inc.

Brad Crabtree
Great Plains Institute

Joseph W. Craft, III
Alliance Coal

Stacey Dahl
Minnkota Power Cooperative

Ruth Demeter
Peabody

Sean Donegan
Satelytics Incorporated

John Duddy
HTI

Frederick R. Eames
Hunton Andrews Kurth, LLP

William Easter
Semplastics EHC LLC

Roderick G. Eggert
Colorado School of Mines

Ron Eller
Tinuum Group LLC

Randy Eminger
Energy Policy Network

Maohong Fan
*School of Energy Resources
University of Wyoming*

David M. Flannery
Steptoe & Johnson, PPLC

Donald Gaston
Prairie State Generating Company, LLC

Danny L. Gray
Green Cement Company

Thomas A. Gray
Tetra Tech Incorporated

Sallie E. Greenberg
*University of Illinois
Illinois State Geological Survey*

Dr. Neeraj Gupta
Battelle

Chris R. Hamilton
West Virginia Coal Association

Tyler Hamman
Basin Electric Power Cooperative

John Harju
*Energy & Environmental Research Center
University of North Dakota*

Clark D. Harrison
Development and Diligence LLC

Roy W. Hill
Clean Energy Technology Association

William Hoback
*Southern Illinois University
Advanced Coal and Energy Research Center*

Robert Hoenes
Caterpillar

Michael J. Holmes
Lignite Energy Council

Marty W. Irwin
Indiana Dept. of Environmental Management

Dennis R. James
Dennis James Consulting LLC

Kim L. Johnson
Gen2, LLC

Kristopher J. Johnson
Tennessee Valley Authority

Dr. Michael Jones, Ph.D.
President
MLJ Consulting, LLC

Newton B. Jones
*International Brotherhood of Boilermakers,
Iron Ship Builders, Blacksmiths, Forgers &
Helpers*

Prakash B. Joshi
Physical Sciences Incorporated

Casey J. Kaptur
Independent Consultant

Michael Karmis
*Virginia Tech, Mining & Mineral Engineering
Virginia Center for Coal & Energy Research*

Kevin C. Kerns
Minus 100 LLC

Tom Kierspe
The SEFA Group

Steven Krimsky
Jupiter Oxygen Corp.

Dr. Holly Krutka
*School of Energy Resources
University of Wyoming*

Vello A. Kuuskraa
Advanced Resources International Inc.

David Lawson
Norfolk Southern Corporation

Douglas A. Lempke
Tri-State Generation and Transmission

Heath Lovell
Alliance Coal, LLC

Leonard J. Marsico
McGuireWoods LLP

Howard G. McClintic
CTC Foundation

Charles D. McConnell
*Center for Carbon Management & Energy
University of Houston*

Liam McHugh
World Coal Association

Charles S. McNeil
NexGen Resources Corporation

Emily S. Medine
Energy Ventures Analysis, Inc.

Gregory Merle
Riverview Energy Corporation

Lee G. Meyer
Carbon Fuels, LLC

Rafic Y. Minkara
Boral Resources LLC

Nancy Mohn
Energy Technologist/Consultant

Betsy B. Monseu
American Coal Council

Michael E. Moore
East-West Strategic Advisors

Dr. Andre Guerin Moreira
Novihum Technologies GmbH

Clark A. Moseley
Navajo Transitional Energy Company

Mike Nasi
Jackson Walker, LLP

Kenneth J. Nemeth
Southern States Energy Board

Rich Nolan
National Mining Association

Brian Norris
Bibb Engineers, Architects and Constructors

Karen Obenshain, Sc.D.
Edison Electric Institute

Jeremy Oden
Alabama Public Service Commission

Mary Eileen O'Keefe
Athena Global Energy Solutions

Jerry J. Oliver
Koch Methanol

Dr. Rudolph Olson, III
CFOAM, LLC

Fredrick D. Palmer
New ERA Carbon Corporation

Jack B. Parkes
Wormser Energy Solutions

Robert M. Purgert
Energy Industries of Ohio

Emily F. Regis
Arizona Electric Power Cooperative

Angila M. Retherford
CenterPoint Energy

Daniel A. Roling
Carbon Recovery Systems

Ted Sanders
Advanced Emissions Solutions, Inc.

Todd Savage
Savage Services

John Schultes
New Steel International, Inc.

Constance Senior
Clean Energy Journal

George Skoptsov
H Quest Vanguard, Inc.

Carolyn Slaughter
American Public Power Association

Deck S. Slone
Arch Resources, Inc.

Charles Snavely
Independent Consultant

G. Scott Stallard
Atonix Digital

Conrad Jay Stewart
Crow Nation Energy

Judd Swift
Synfuels Americas Corporation

Brian Thompson
Komatsu Mining Corporation

John W. Thompson
*Fossil Transition Project
Clean Air Task Force*

Beth Valiaho
International CCS Knowledge Centre

Joseph W. Valis
BOVARO Partners, LLC

John N. Ward
National Coal Transportation Association

Sharla Wells
Big Rivers Electric Corporation

Charles R. Wesley, IV
Thoroughbred Resources, LP

R. William (Bill) West
Arq Limited

Tyler White
Kentucky Coal Association

Kemal Williamson
Peabody

Ken S. Wilmot
Associated Electric Cooperative Incorporated

James Wood
Energy Institute
Advanced Coal Technology Consortium
West Virginia University

Gregory A. Workman
Dominion Energy, Inc.