

Coal to Products



Building the “Carbon Valley” for Coal

Ken Woodring – Director of Operations, Ramaco Carbon

Wyoming State Legislature — Joint Committee on Minerals, Business and Economic Development
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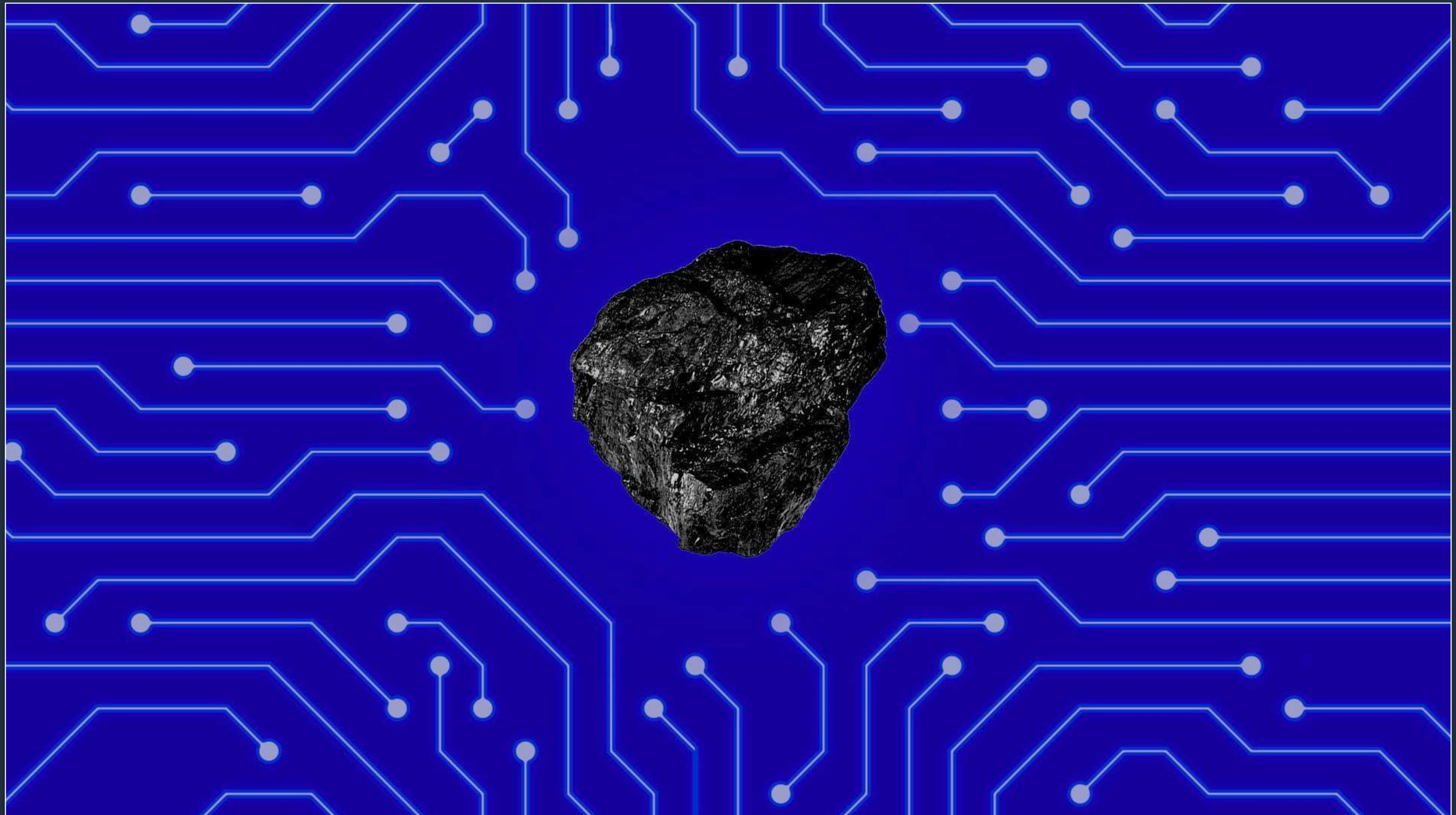
Does Coal Have a Future?

The Jury is Still Out

- Thermal coal may not prevail against natural gas and renewables in the “race to the bottom” as the cheapest fuel for power generation.
- Yet, the United States has the world’s largest and cheapest coal reserves.
- 95% of all coal produced worldwide is currently burned for power generation.
- Only 5% is used to make higher value products, like met coal for steel. Met coal sells for a higher price, currently almost ~20x Powder River Basin (PRB) coal prices.



Perhaps coal *is* the future...



“Carbon Valley” Could be as Disruptive as Silicon Valley

Today

- Coal is the cheapest source of carbon. But most carbon products, such as carbon fiber and graphene, are expensive.
- Why? They’re now made with petroleum.
- Coal and petroleum are the most important sources of carbon, but the cost of carbon from petroleum is 20 times higher than the cost of carbon from coal.

Future Opportunity

- Using the carbon from coal could dramatically reduce the cost of many products, ushering in a wave of innovation in advanced materials and manufacturing.
- Like the internet and early computing technology, coal can be used to enable low cost disruption on a massive scale.

Who We Are

Ramaco Coal, founded in 2011, is a coal-based conglomerate with operations in five states. It consists of three separate companies:

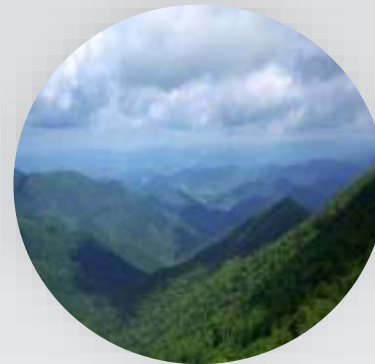


RAMACO RESOURCES

A publicly traded met coal producer, with five new met coal mines opened in the Eastern U.S. in the past year.

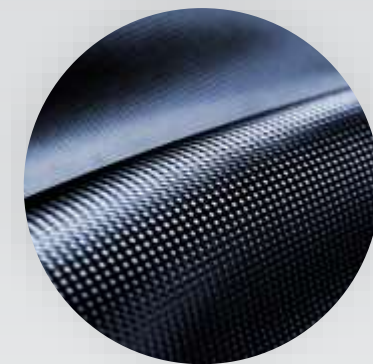
Projected annual production of 4+ million tons of quality met coal.

www.ramacoresources.com



RAMACO ROYALTY

A private company that owns approximately 200 million tons of metallurgical coal reserves in Central Appalachia.



RAMACO CARBON

A private Wyoming-based company focused on "Coal to Products," and partnered with national laboratories, universities, and industry groups.

www.ramacocarbon.com

Ken Woodring — Director of Operations, Ramaco Carbon

- Mining Executive with 50 years experience in coal
- Previously Executive Vice President of Operations at Arch Coal during a time of key benchmarks:
 - Acquired Thunder Basin Coal Company
 - Expanded Black Thunder into the Thundercloud LBA
 - Acquired and integrated Triton Coal
 - Black Thunder became one of the two largest coal mines in the world
- With Ramaco since 2012, including initial conceptual project planning for the Brook Mine for thermal market consideration
- In Q3 2014, during market decline for coal industry, we innovated as Wyoming's private sector vanguard, planning how the Brook Mine might pioneer a shift to “coal to products” research and manufacturing

Investing in Innovation

- **Ramaco Carbon** is the nation's first pure "Coal-Tech" company.
- We are the **only strategic coal group** pursuing a vertically integrated resource, technology research and manufacturing based approach to create "**Coal to Products**".
- We are **100 percent privately funded and fully capitalized**.
- We're privately investing to create an ecosystem of innovation in Wyoming, in a sector that represents the state's biggest opportunity for job creation.



Our Operations



**COAL
RESERVE**

Brook Mine, with 1.1 billion tons of coal resource on a 15,000 acre site six miles north of Sheridan, WY. Now under revised permit review.



**RESEARCH
PARK**

The iCAM (Carbon Advanced Materials Center) will be completed by early Summer 2019. It will house national laboratories already under working agreements, university and private research groups and strategic manufacturing partners. We will conduct applied research to commercialize coal-based carbon products, bench to pilot stage.



**INDUSTRIAL
PARK**

A 100+ acre “coal to products” mine-mouth manufacturing park named iPark. Plants will use research from the iCAM and coal from the Brook Mine to manufacture advanced carbon products.

The Brook Mine

- In October 2018, Ramaco Carbon submitted a revised mine permit application for the Brook Mine, on mineral reserves and land it owns in Sheridan County.
- With strengthened commitments around hydrology, quality of life, and subsidence, it provides the most far reaching environmental protections of any coal mine permit yet submitted in Wyoming.
- The revised mine permit for the Brook Mine meets or exceeds all required state and federal requirements.
- If approved, it would be the first new Wyoming coal mine permit issued in 40 years.



Our recent Brook Mine application, setting a new gold standard for Wyoming mining operations.

The iCAM



A coal innovation
campus designed by
acclaimed Wyoming
architect Steve Dynia.
Completion by
Summer of 2019



A photograph of four people in a hallway. On the left, a man in a dark suit and red tie is partially visible. Next to him is an older man in a blue suit and blue tie. Then a younger man in a blue suit, white shirt, and red tie with a name tag that says 'TOM TAKA'. On the right is a woman with blonde hair, wearing a red cardigan over a patterned top, holding a folder. They are all looking towards the right. The hallway has white walls and a sign that says 'LAB' is visible on the left wall.

Unique Partners

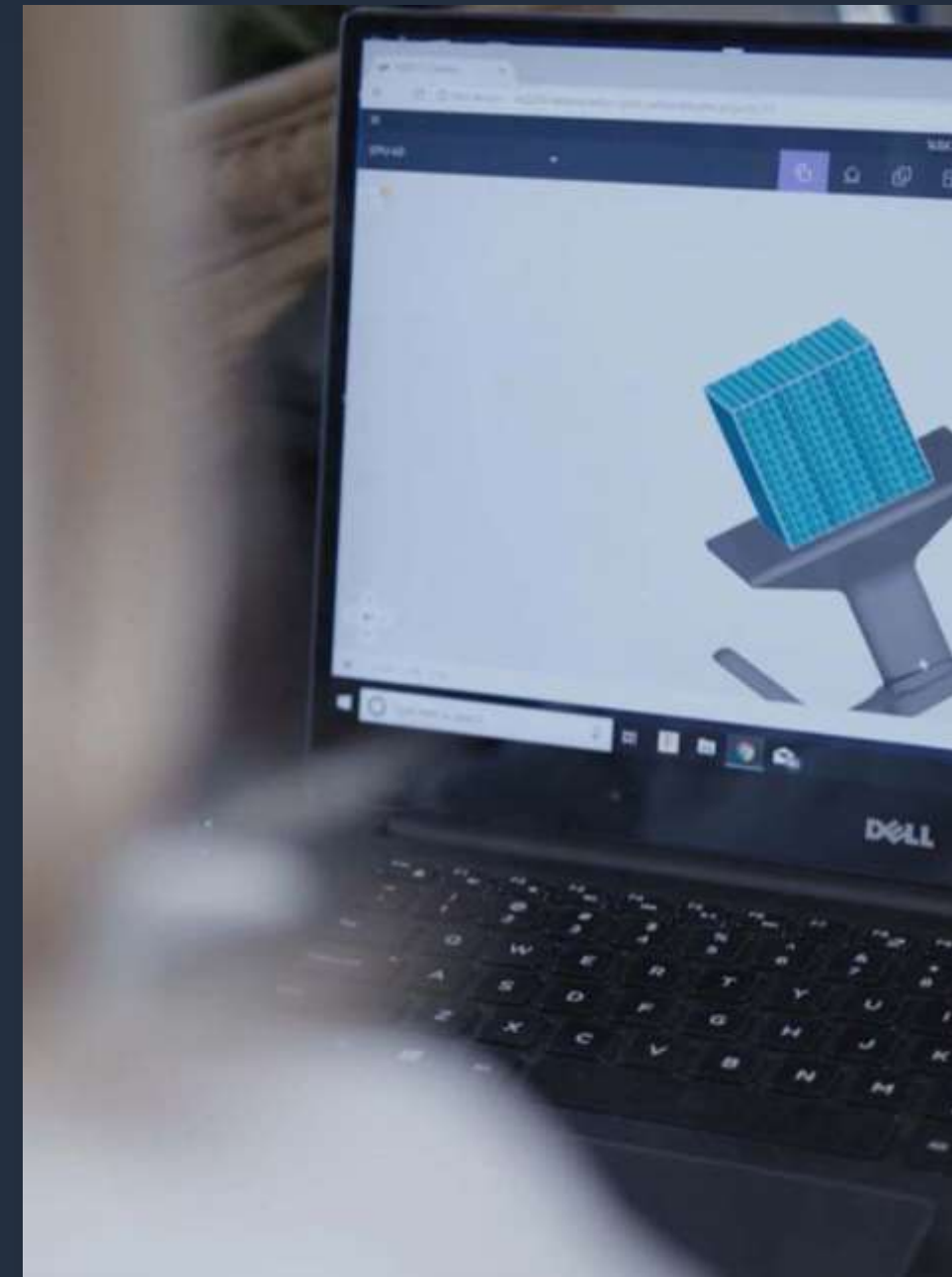
- Ramaco is privileged to be working with some of the top U.S. **research institutes, universities, and strategic groups**, who form our core research and development team. Most came together this summer for R3, a “coal-to-products” research conference we organized in Sheridan.
- Ramaco’s chairman has been asked to chair a White Paper from the **National Coal Council to the U.S. Department of Energy, requested by Secretary Rick Perry**, on “New Markets for Coal to Products”. The report will be delivered in April 2019.
- Ramaco and many of its partners are involved in a **DOE** project to develop coal as a low cost precursor for carbon fiber to be used in vehicles. We call it “**Coal to Cars.**”

Partners include:

- National Energy Technology Laboratory
- Oak Ridge National Laboratory
- MIT- The Grossman Materials Group
- Fluor Corporation
- Carbon, Inc.
- Univ. of Illinois-Chicago
- Western Research Institute
- Southern Research Institute

Our Focus

- Ramaco is focusing on four broad uses for Brook Mine coal:
 - 1) Coal to Carbon Fiber
 - 2) Coal to Carbon Building Products
 - 3) Coal to Carbon Advanced Materials
 - 4) Coal to Medical Technology Products
- We seek uses that marry advanced materials and advanced manufacturing technologies.
- These uses have a higher margin value proposition and can require large coal volumes.
- The Key: Displace petroleum as the preferred lower cost carbon feedstock.



The Displacement Potential of Coal

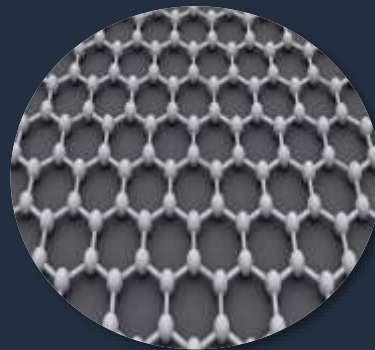
Coal's potential is to make advanced materials that are **stronger, lighter...and cheaper.**

The “Key” to coal's advantage... is **cost**. Materials from coal can be made cheaper than from petroleum. These materials include:



Carbon Fiber

Carbon fiber is 50% the weight of aluminum but 4X as strong. It is 25% the weight of steel but 2X as strong.



Graphene

Used to conduct heat and electricity, this material is thinner than paper and can be harder than a diamond.



Graphite

Can be used to make brake linings, lubricants, and molds in foundries, as well as in the production of steel.

The Margin Multiplier of Advanced Manufacturing



COAL FEEDSTOCKS

\$30-60/ton (2017 spot price)

ADVANCED 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

Coal to Cars

- Of roughly 100 million vehicles made each year, carbon fiber is used in less than 100,000 — despite benefits in gas mileage, strength, and more.
- The barrier is carbon fiber's high cost.
- We need to drive the price of the coal-based precursor beneath the “tipping point.” Carbon fiber then becomes an affordable alternative to steel.
- Carbon fiber cars then move from niche markets — such as F1 racing — to mass market.



Coal to Building Products

Another disruptive market for coal is “Building Products.” Building products have the potential to require greater coal volumes than carbon fiber.

The range of product uses is practically endless, and include:

- **Rebar** — Carbon fiber rebar can provide flexibility to concrete structures, is lighter than current rebar, and does not rust.
- **Roofing** — Coal-based asphalt roof shingles could become a regular feature of buildings.
- **Repair Aging Infrastructure** (think bridge renovations): Can be molded around existing older infrastructure to provide structural strength, increasing lifespan by 2-3x.



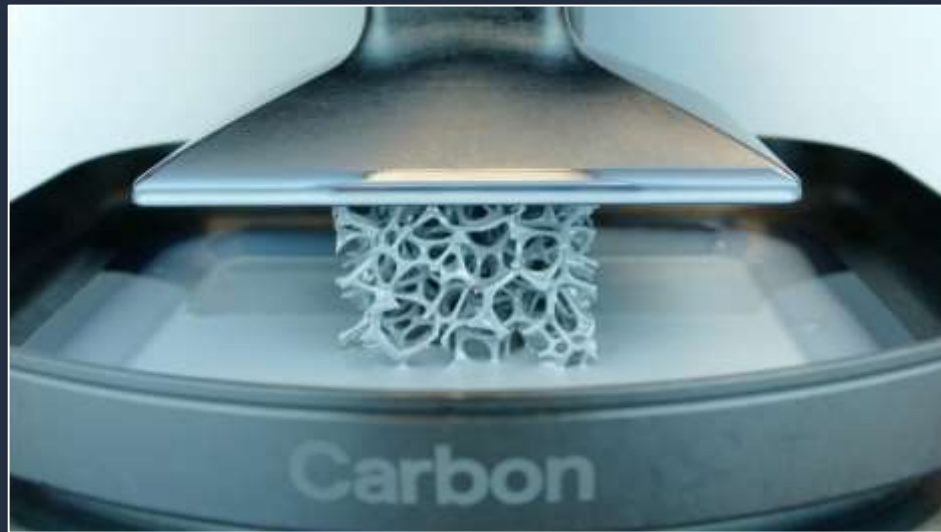
Coal to 3D Printing Cycle



Wyoming iPark
SpeedCell Printers



Ramaco 3D: Now Operational in Sheridan, WY



- With technology from Silicon Valley-based Carbon3D, we can produce most parts and products faster and cheaper.
- Our 3D manufacturing operation is now open for business, and is already producing products for local groups and companies.



Advanced 3D Manufacturing: A New Use for Coal

The Path Forward: Key Points

#1

The past few years have been very difficult for coal industry. To survive the industry must adapt and innovate ... it is time to think outside the box.

#2

Ramaco is privately building the first vertically integrated “Coal Tech” platform today in Wyoming and is the only industry partner in this space. We are creating a Carbon Valley in Sheridan.

#3

U.S. has both the resource base and the technological prowess to fundamentally reorient the coal industry. Uniquely, the U.S. can become the cornerstone of an advanced materials and manufacturing revolution.

#4

Innovation and research is the first step. R&D must then be leveraged and supported to create widespread commercial applications.

#5

Federal government support for new research is essential to realizing the scale of the opportunity. But local government must be cautious to not put a “Thumb on the Scale” and stifle or compete against private innovation.

#6

Remember...It starts with a lump of coal and the Power of Carbon...



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