

Coal to Products



A New Carbon Valley for Coal...

***Randall Atkins- Chairman and Chief Executive, Ramaco Coal, LLC
Ramaco Research Rodeo July 2018***

Does Coal Have a Future?

- **Yes...**but not the way everyone thinks today.
- The jury is still out for the use of Coal as the long term preferred feedstock for power generation ... Thermal Coal may not prevail against subsidized renewables and low cost gas in a “race to the bottom” as the cheapest base load fuel.
- Yet, the United States has the world’s **largest** and **cheapest** coal reserves.
- **The Problem**-Currently, 95% of all coal produced worldwide is burned for **power generation**.
- Only 5% is used to make **higher value products**, think met coal for steel. Met coal sells for a **higher price**, currently almost ~20x PRB coal prices.

Coal can be the Functional Equivalent of the Internet for Advanced Materials and Products

The Opportunity:

- Coal is the **cheapest** source of carbon. Today most carbon products are expensive because they come from petroleum.
- A ton of Coal and Petroleum each contain roughly 75% carbon by weight. A ton of Petroleum costs \$500. A ton of PRB coal costs \$12.
A “No-brainer”... Let’s use carbon from coal.
- **So... use “Carbon from Coal” as the low cost “Disruptor” for manufacturing advanced materials and products**
 - **Think of coal as like the internet.... it can be used to achieve low cost disruption on a massive scale.**



The Objective:

- ❑ Create an **Disruptive Ecosystem** to develop carbon product uses with high margins... that also require the use of large volumes of coal as the basic carbon feedstock. Think thermal coal priced like met because of end use margins....

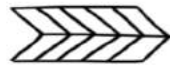
- ❑ **The Result-** We build an innovative, disruptive higher tech future for the coal industry, independent of power trends and related environmental issues.
 - ❑ We **Disrupt...but in Good Way!!!**

Positive Disruption



INNOVATION

DISRUPTION



DOING THE SAME
THINGS A BIT
BETTER

DOING NEW
THINGS

MAKING THINGS THAT
MAKE THE OLD THINGS
OBSOLETE

Carbon...

the Secret Agent of *Mass Disruption*

- ❑ Carbon is becoming the dominant “***advanced material***” of the 21st Century... think carbon fiber, graphene, graphite and carbon resins.
- ❑ The goal is to make these advanced materials for a lower cost from coal. This precursor substitution could be vastly disruptive. Cheaper materials from coal could replace or enhance most **metals** (i.e. steel, aluminum,) and **basic building products** (i.e. cement, asphalt, rebar, roof shingles).
- ❑ Carbon also has applications in **chemicals, resins** and even **life sciences**.
- ❑ All of these are fast-growing, game changing uses, **that can require tremendous volumes of coal**. In some cases think 100 million tons+ per use. The US mined 725 million tons in 2017.
- ❑ Only a few new disruptive uses **creates a demand inflection point for the entire coal industry**.

Who We Are

Ramaco Coal, founded in 2011, is a coal-based conglomerate with operations in five coal producing states, and three separate companies. We cover most all of the bases:

- **Ramaco Resources, Inc. (NASDAQ –METC)**: A public met coal producer. In 2017 became the first new coal IPO in the U.S. in a decade. Opened five new met coal mines in the past 12 months. Operations in West Virginia, Virginia, Pennsylvania and Kentucky. Projected full annual production of approximately 4+ million tons of high quality/low cost metallurgical coal.
www.ramacoresources.com.
- **Ramaco Royalty, LP**: A private company that owns approximately 200 million tons of metallurgical coal reserves in Central Appalachia.
- **Ramaco Carbon, LLC**: A private Wyoming-based company focused on “**Coal to Products**.” www.ramacocarbon.com.

Ramaco Coal Organizational Chart

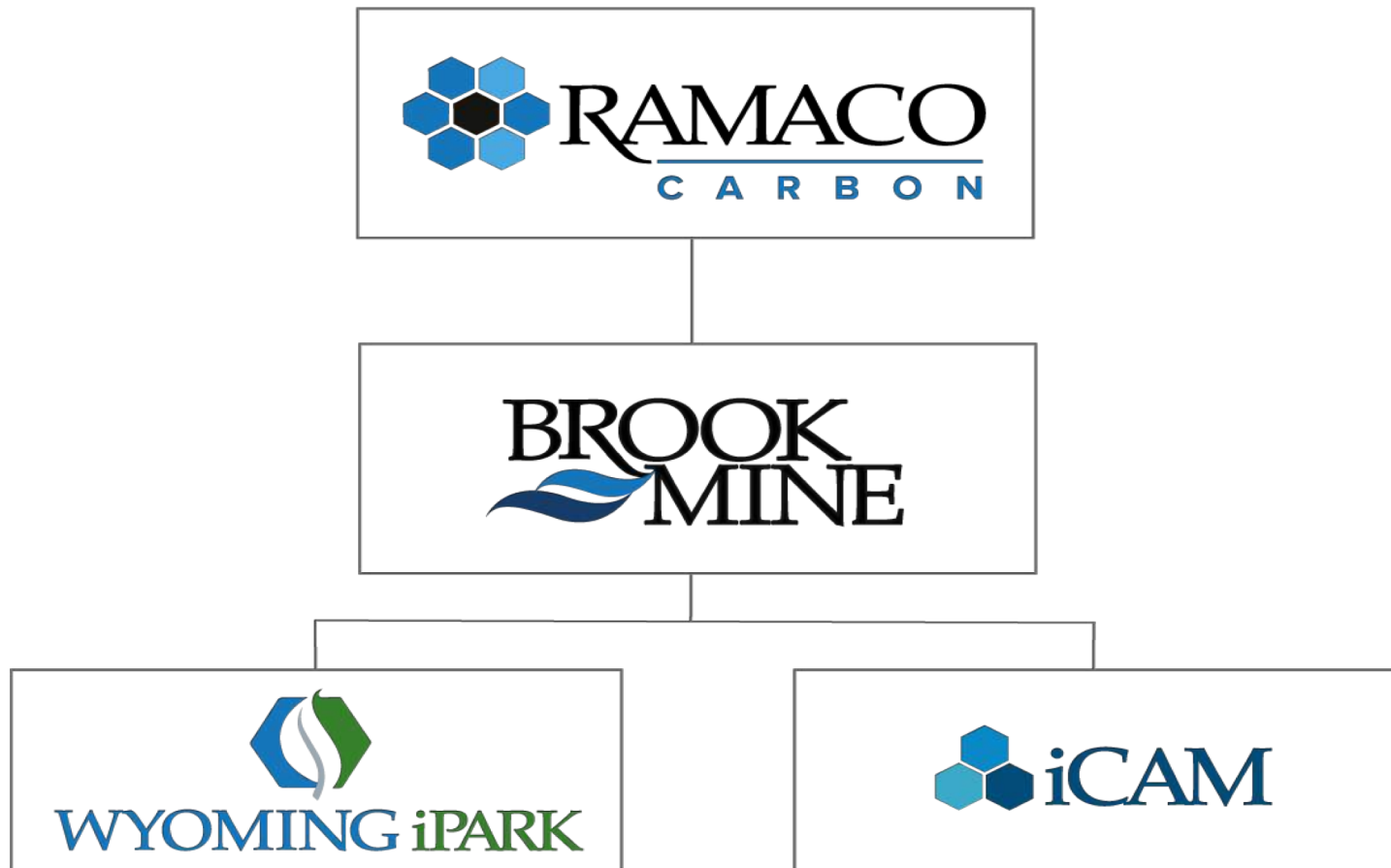


Ramaco Carbon

The First Vertically Integrated Carbon Tech Company

Ramaco Carbon is the first vertically integrated “**Carbon-Tech**” company, with our carbon derived from Coal. We are also the **only strategic industry group** with a platform that pursues a resource, research and advanced manufacturing based approach to new coal uses. We are an incubator of “**Coal to Products**” from Carbon. Our operations are :

- ❑ **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 final permit review.
- ❑ **RESEARCH PARK (iCAM - Carbon Advanced Materials Center)**: Breaking ground this summer. The **iCAM** will house national laboratories, 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 (Wyoming iPark)**: A 100+ acre “**coal to products**” mine-mouth industrial park. Plants will utilize research from the **iCAM**, coal from the **Brook Mine** and manufacture advanced carbon products.



The Trilogy...the First “Carbon-Tech” company with Coal Resources, Product Research and an Advanced Manufacturing Center

Partners

- ❑ **Ramaco** is privileged to be working with many of you, who constitute some of the top **U.S. national labs, research institutes, universities, and strategic groups involved with coal and carbon related research.** This forms the core of the **Ramaco's** research and development efforts.

- ❑ Some members are:
 - **National Energy Technology Laboratory**
 - **Oak Ridge National Laboratory**
 - **Western Research Institute**
 - **Carbon, Inc.**
 - **Fluor Corporation**
 - **MIT- The Grossman Materials Group**
 - **Southern Research Institute**

- ❑ Along with Western Research and other partners, **Ramaco** is part of a **U.S. Department of Energy grant** to develop coal as a low cost precursor for carbon fiber to be used in vehicles. We call it **“Coal to Cars.”**

Our Focus

- ❑ Ramaco is focusing on **three** broad uses:
 - 1) **Coal to Chemicals**
 - 2) **Coal to Carbon Fiber**
 - 3) **Coal to Building Products**

- ❑ We seek uses that can marry **advanced materials and advanced manufacturing technologies.**

- ❑ These uses all possess products with a high margin value proposition and that will require large coal volumes as precursor feedstock.

- ❑ The reality is that new uses will emerge that we can probably not even guess at now. You think Steve Jobs originally planned on a mobile phone being Apple's main line of business ?

The “Advanced Materials” Displacement Potential of Coal

- ❑ Coal’s Potential is to make Advanced Materials that are Stronger and Lighter... and Cheaper.

- ❑ Example- Carbon Fibers
 - Carbon fiber is 50% the weight of aluminum but 4X as strong
 - Carbon fiber is only 25% the weight of steel but 2X as strong

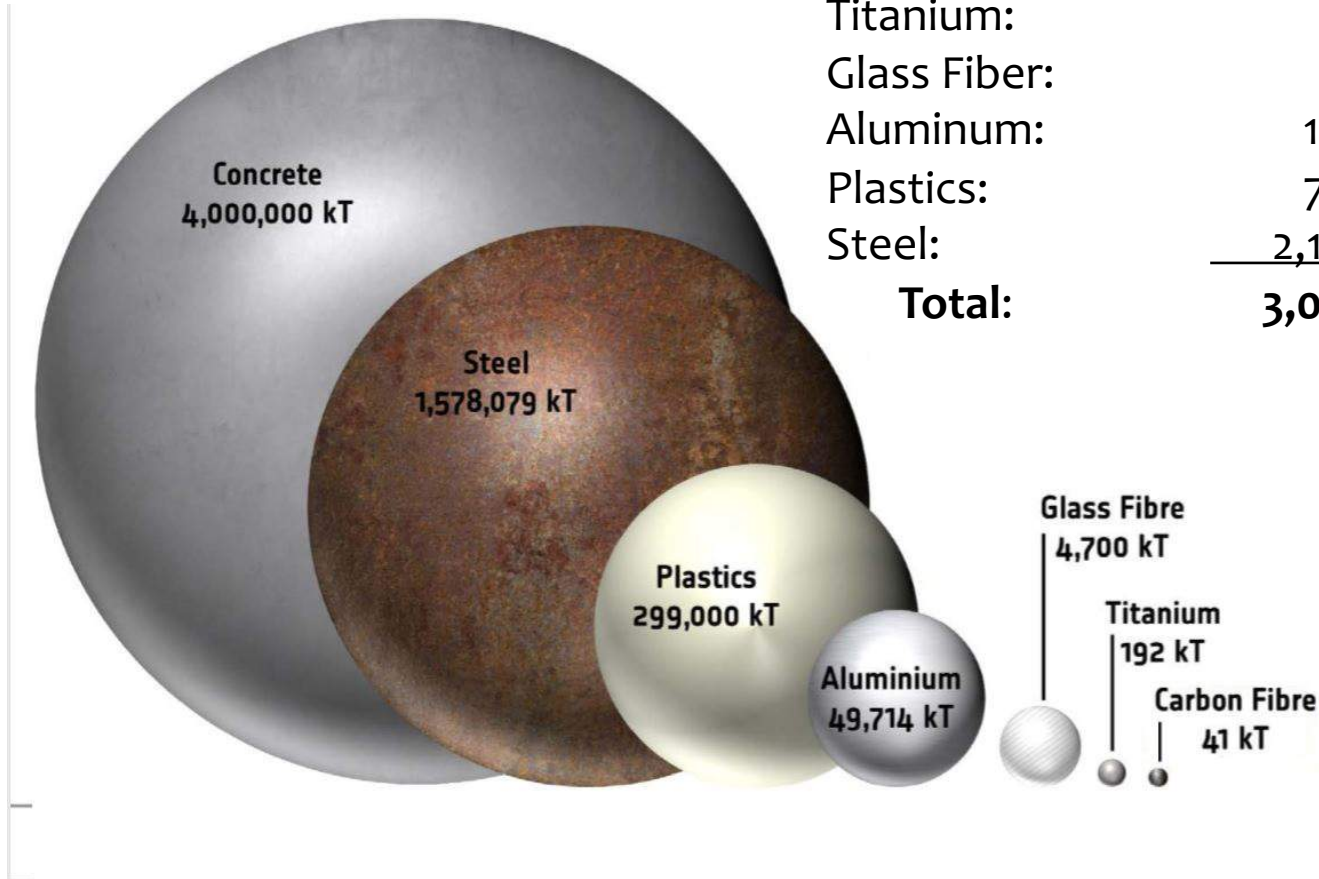
- ❑ **The “Key” to Coal’s Advantage... is cost.** Materials from coal can be made cheaper, than from petroleum.

- ❑ **The Goal:** Displace petroleum as the preferred **lower cost carbon feedstock.**

Material Displacement Opportunities are Huge

Annual amount of coal needed to replace:

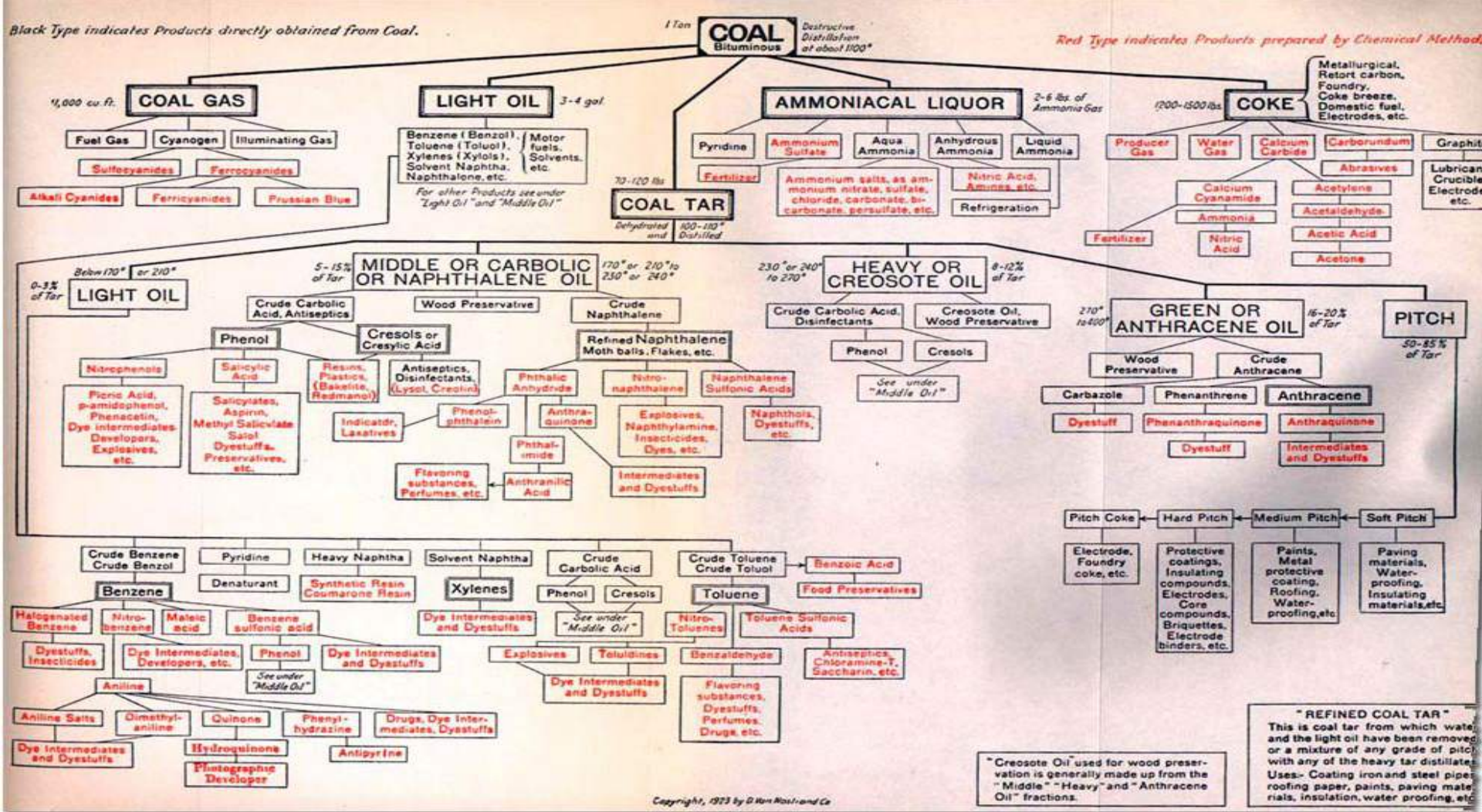
Carbon Fiber (12% CAGR):	225,000 MT
Titanium:	1,054,000 MT
Glass Fiber:	25,827,000 MT
Aluminum:	136,577,000 MT
Plastics:	764,902,000 MT
Steel:	<u>2,167,691,000 MT</u>
Total:	3,096,276,000 MT



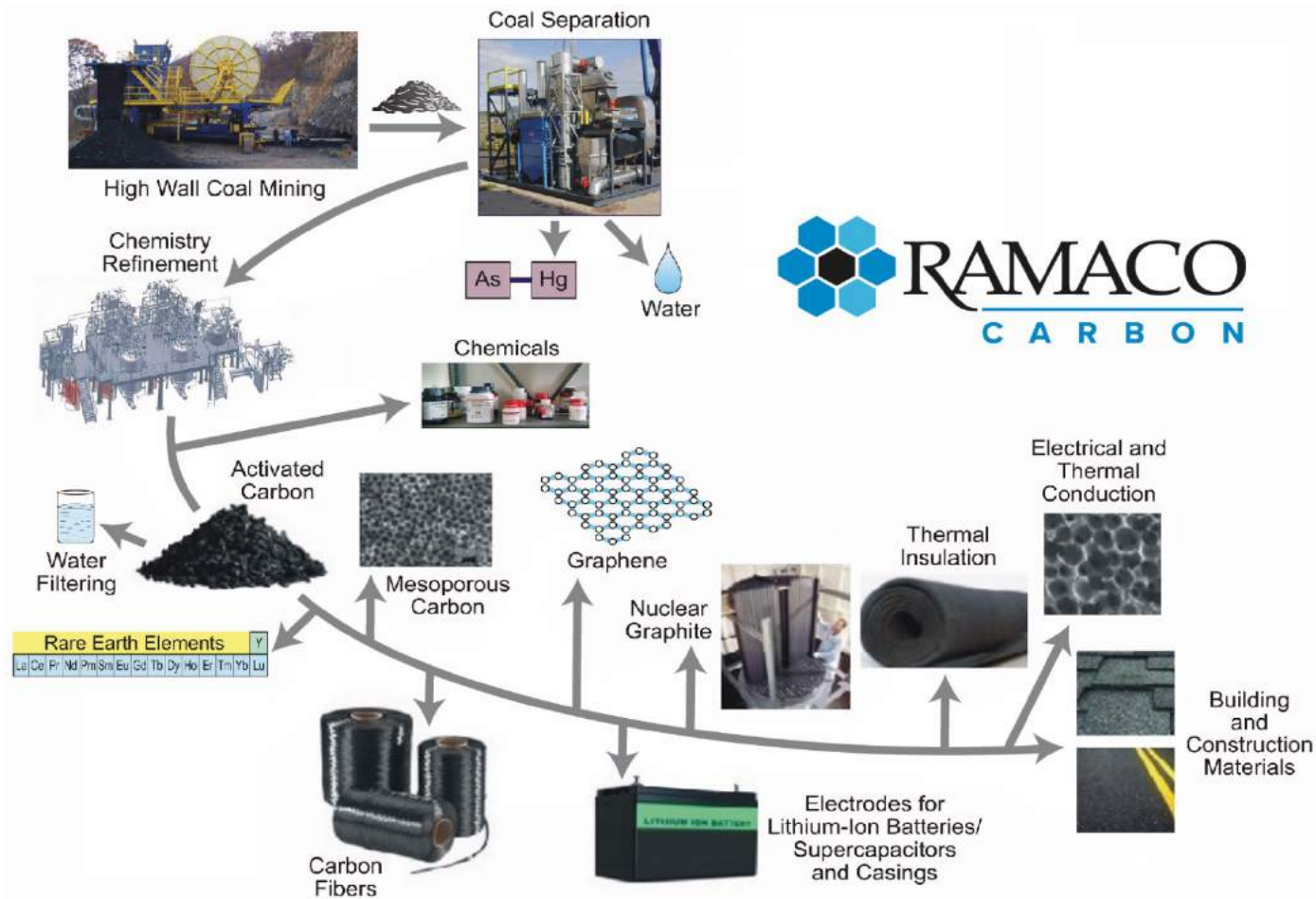
Let's Go Back to the Future with Coal



Your Grand Dad's Coal Tree (circa 1923)



A Few New Trunks on the Tree Coal



Coal to Carbon Fiber

Carbon Fiber is used today, with reinforced plastics (CFRP), to displace steel and aluminum **everywhere** where “**light weighting**” is important, and cost ***is not***.

Examples include:

- Fishing rods, bikes, golf shafts, tennis racquets
- 40% of commercial airliners, 31% of fighter jets

THE PROBLEM IS COST: Today, carbon fiber is 8x more expensive than steel and 2x more expensive than aluminum.

THE REASON IS PETROLEUM: Today's Carbon fiber precursor comes from **petroleum**. The cost is about \$15-\$20+ per pound.

If we can drop the price of carbon fiber precursor through R&D below \$5 per pound, it is a game changer. Carbon Fiber replaces steel and aluminum.

Coal to Cars

- ❑ Of roughly 100 million vehicles made each year, carbon fiber is used in less than 100,000. **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 a niche market to mass market.**

Coal to Cars...The Evolution

FIRST



High End
& Niche

NOW



Low Volume
Production of
Affordable Car

NEXT



Mass Market
Appeal



High End
Low Volume
Hand Layup



Low Volume
Production



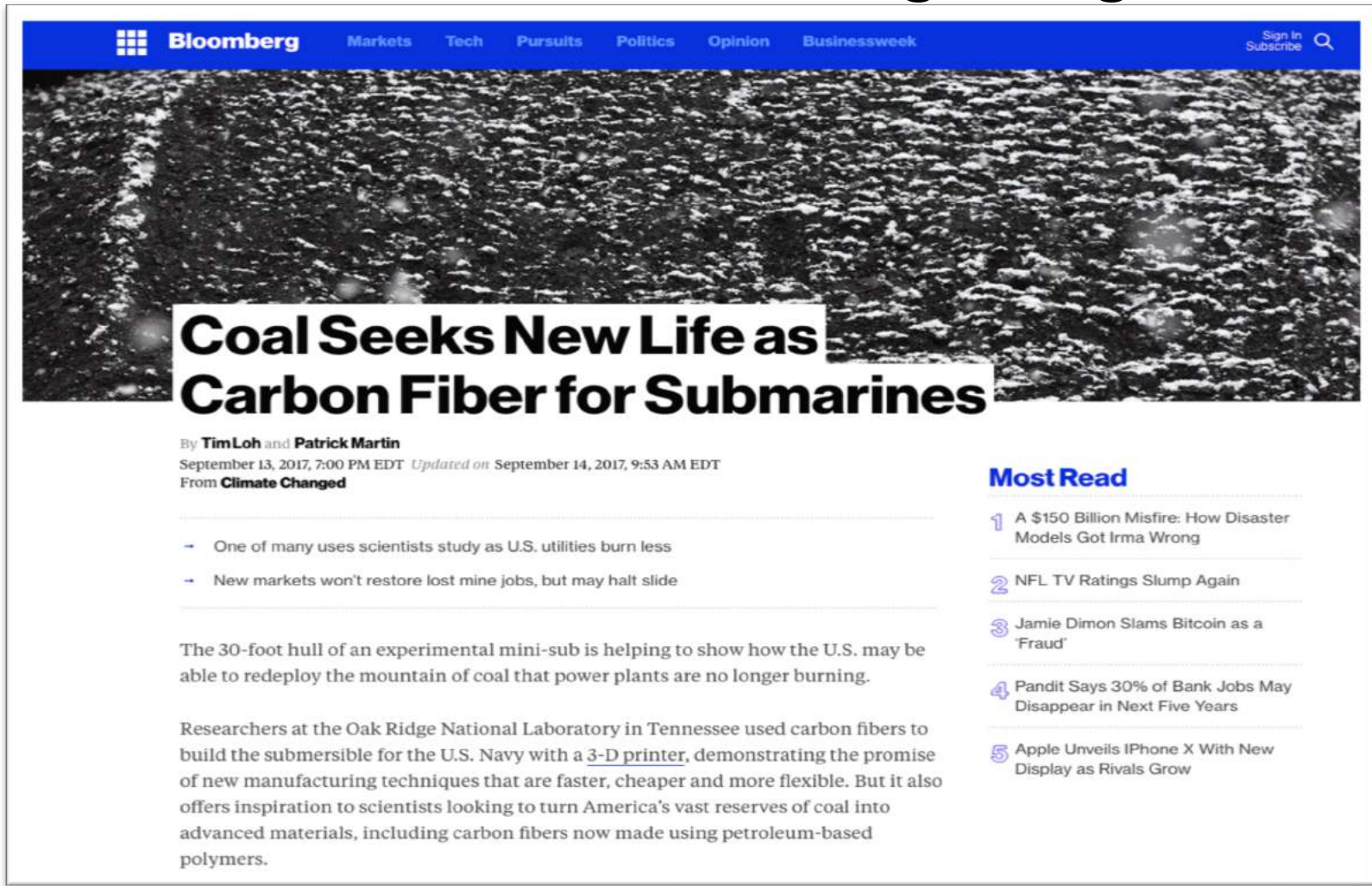
High Volume
Production

Ramaco's New Carbon Fiber Family Car



(aka the “all Carbon Fiber” McLaren Carbon Series LT “Special Edition”)

Coal to...Many Things The Revolution is Beginning



The image is a screenshot of a Bloomberg news article. At the top, there is a blue navigation bar with the Bloomberg logo and various category links: Markets, Tech, Pursuits, Politics, Opinion, and Businessweek. On the right side of the bar, there are links for 'Sign In' and 'Subscribe' with a search icon. Below the navigation bar is a large black and white photograph of a coal pile. Overlaid on the bottom left of the photo is the article's title in large white text: 'Coal Seeks New Life as Carbon Fiber for Submarines'. Below the title, the authors 'Tim Loh and Patrick Martin' are listed, followed by the date 'September 13, 2017, 7:00 PM EDT' and a note that it was updated on September 14, 2017. The article is categorized as 'Climate Changed'. Below the byline, there are two bullet points: 'One of many uses scientists study as U.S. utilities burn less' and 'New markets won't restore lost mine jobs, but may halt slide'. The main text of the article begins with 'The 30-foot hull of an experimental mini-sub is helping to show how the U.S. may be able to redeploy the mountain of coal that power plants are no longer burning.' and continues to describe the use of carbon fibers in building a submersible for the U.S. Navy. On the right side of the article, there is a 'Most Read' section with a list of five other articles, each with a numbered icon and a brief title.

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Coal Seeks New Life as Carbon Fiber for Submarines

By **Tim Loh** and **Patrick Martin**
September 13, 2017, 7:00 PM EDT Updated on September 14, 2017, 9:53 AM EDT
From **Climate Changed**

- One of many uses scientists study as U.S. utilities burn less
- New markets won't restore lost mine jobs, but may halt slide

The 30-foot hull of an experimental mini-sub is helping to show how the U.S. may be able to redeploy the mountain of coal that power plants are no longer burning.

Researchers at the Oak Ridge National Laboratory in Tennessee used carbon fibers to build the submersible for the U.S. Navy with a 3-D printer, demonstrating the promise of new manufacturing techniques that are faster, cheaper and more flexible. But it also offers inspiration to scientists looking to turn America's vast reserves of coal into advanced materials, including carbon fibers now made using petroleum-based polymers.

Most Read

- 1 A \$150 Billion Misfire: How Disaster Models Got Irma Wrong
- 2 NFL TV Ratings Slump Again
- 3 Jamie Dimon Slams Bitcoin as a 'Fraud'
- 4 Pandit Says 30% of Bank Jobs May Disappear in Next Five Years
- 5 Apple Unveils iPhone X With New Display as Rivals Grow

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.

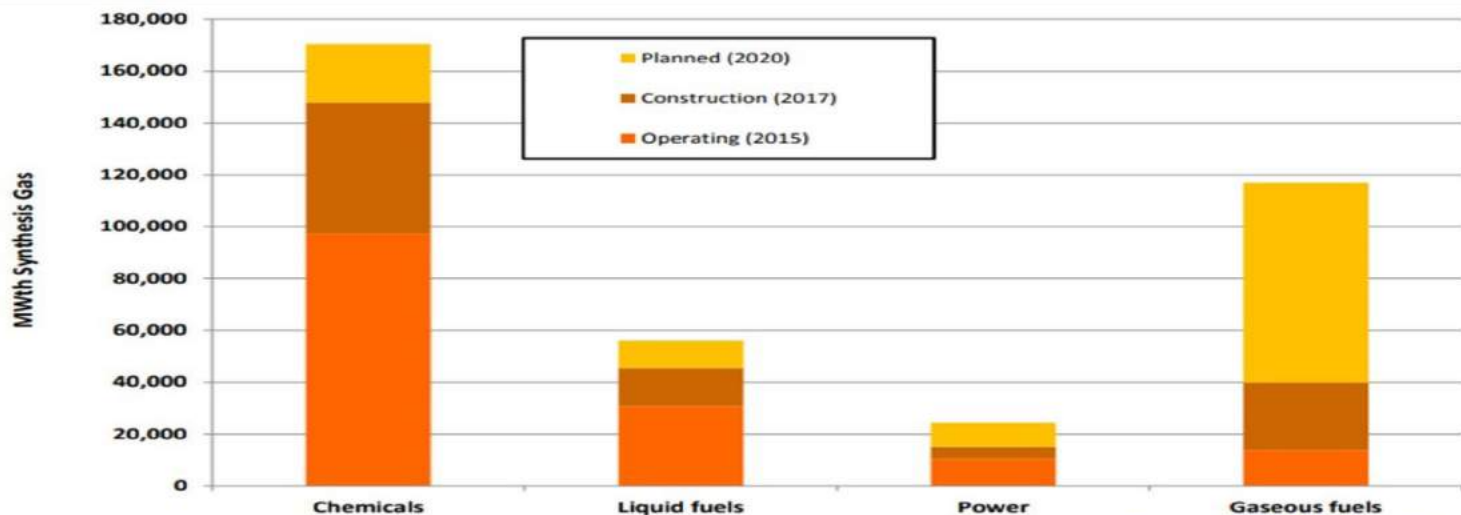
- ❑ The range of product uses is practically endless.
 - **Rebar:** Carbon fiber rebar can provide flexibility to concrete structures, is lighter than current rebar, and does not rust.

 - **Coal Based Asphalt Roof Shingles**

 - **Repair Aging Infrastructure (think bridge renovations):** Can be molded around existing older infrastructure to provide structural strength. The life span of infrastructure can be increased by 2-3x.

Coal to Chemicals

- ❑ Coal to chemicals has been practiced for decades . We are first targeting Resins for 3D Advanced manufacturing. We want to make the “Software” not the computer...
- ❑ The growth of the olefins markets, as well as price dynamics in coal and other feedstocks (CH₄ and CO₂) create other new opportunities.
- ❑ We are exploring some of these technologies with our partners, specifically Fluor, who was the EPC contractor for coal to liquids projects like Sasol II and III, as well as WRI and SR.



Source: GSTC Database, 2016

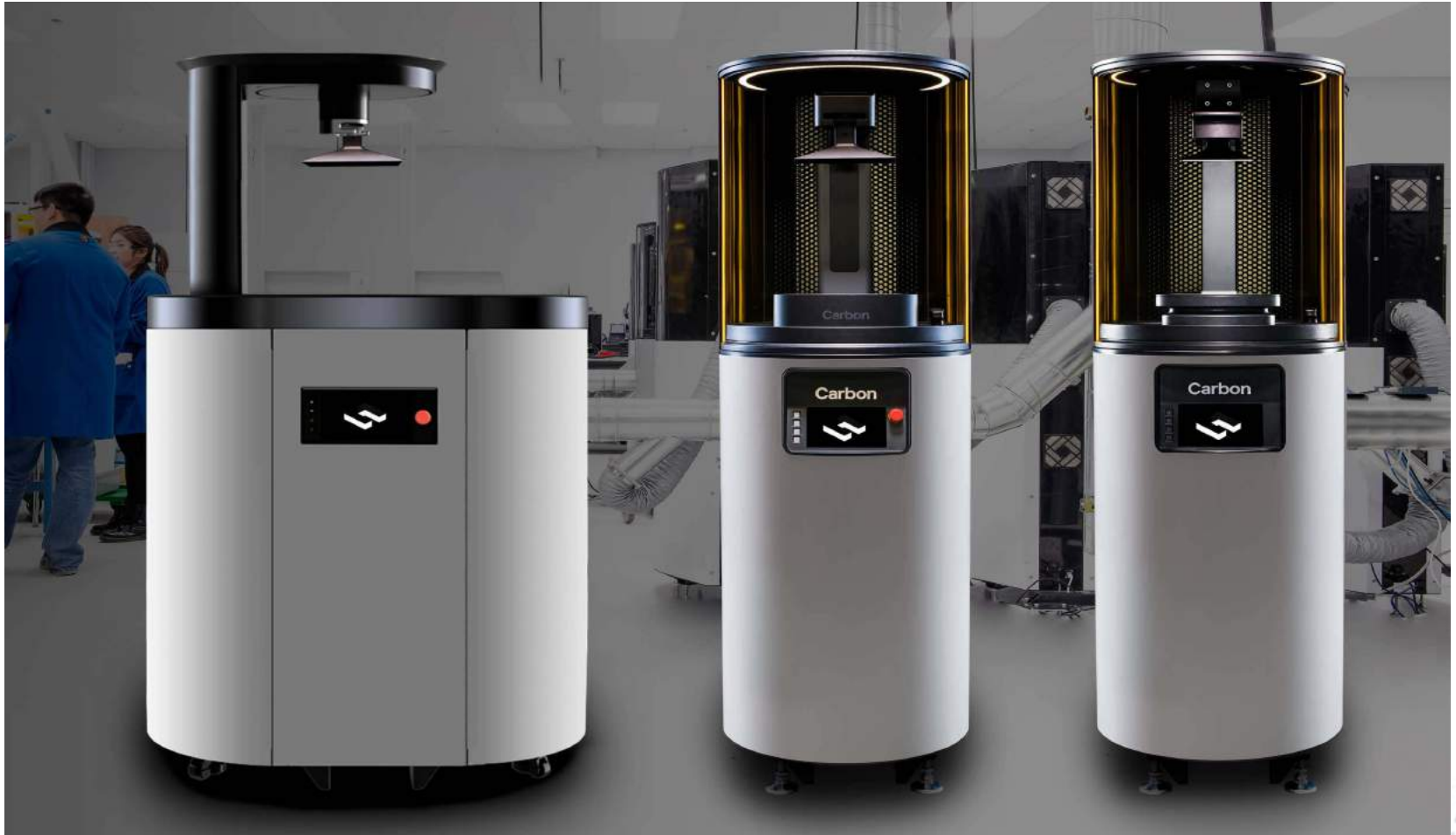
Combine Chemicals from Coal with Advanced Manufacturing

- ❑ Silicon Valley-based company **Carbon, Inc.**, is revolutionizing 3D printing. Its “*CLIP-Continuous Liquid Interface Process*” uses ultraviolet light, oxygen and carbon resins to print solid materials.
- ❑ Ramaco Carbon has entered into a production partnership with **Carbon, Inc.** to create advanced carbon-based products, ultimately from coal based carbon resins.
- ❑ **Ford, BMW and Adidas** are already working with Carbon, Inc.
- ❑ **Ramaco** takes delivery of several Carbon 3D printers this spring to manufacture a wide range of products.
- ❑ This is not “smoke stack” manufacturing...

Wyoming iPark Manufacturing in 3D Printing “Farms”



Our Assembly Line- “Speedcell” 3D Printers



The Way Forward

- ❑ Coal needs its own “**Carbon Valley**”. **Ramaco** is designing into the future with a Coal Tech “Platform” that represents the first targeted steps by an industry partner.
- ❑ At Ramaco are more interested in creating the ecosystem, or the Platform, than any one Product. Who knows where this will lead.
- ❑ U.S. is blessed that it has both the resource base and the technological prowess to fundamentally reorient the world’s coal industry. We can be **the cornerstone of an advanced materials and manufacturing revolution**.
- ❑ **Innovation and research** is the first step. That is why we are here today.
- ❑ **The R&D needs to focus on potential widespread Commercial applications which use “lots of Coal” at good margins.**
- ❑ Government research support is **essential** to realizing the scale of the opportunity.
- ❑ Remember... It starts with “**Joel**” the **lump of coal** and the **Power of Carbon**....



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