

Coal to Products



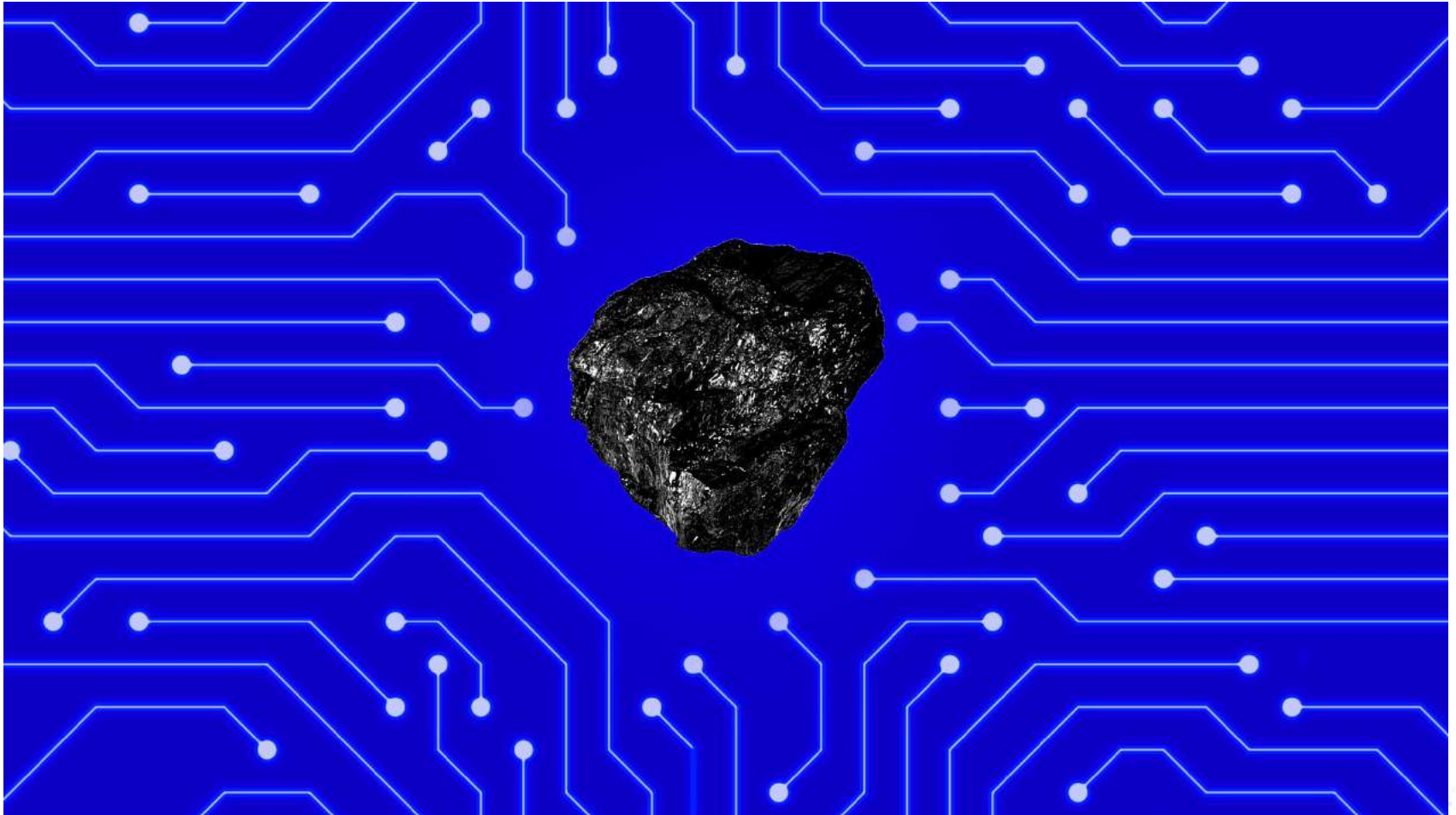
A “Carbon Valley” for Coal

***Charles Atkins- Director of Research and Development, Ramaco Carbon’s iPark
Global Syngas Technologies Conference, October 2018***

Does Coal Have a Future?

- ❑ The jury is out... Thermal Coal may not prevail against renewables and gas in the “race to the bottom” as the cheapest base load fuel for power generation.
- ❑ 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.

Perhaps Coal *is* the Future?



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

The Opportunity:

Coal is the cheapest source of carbon. But most carbon products are expensive.

Why? They now 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.

The Objective:

- So... use “Carbon from Coal” as the low cost “Disruptor” for making advanced materials using advanced manufacturing
- Think of coal like the internet... it can be used to achieve low cost disruption on a massive scale.



The Road Map:

- ❑ Create an **Disruptive Platform** to develop carbon product uses which have high margins... but that also requires large volumes of coal as the basic carbon feedstock. Think thermal coal priced like met, because of end use margins....
- ❑ **The Result**- An innovative higher tech future for the coal industry, independent of power trends and related environmental issues.
 - ❑ **Disruptive Perhaps....**

Carbon...

the “Secret Agent” of *Mass Disruption*

- ❑ Carbon is becoming the dominant “advanced material” ... think carbon fiber, graphene, graphite and carbon resins.
- ❑ *Today most carbon products are derived from petroleum precursors. If made from coal there is a potential 30x cost savings in basic feedstock.*
- ❑ If these advanced materials are made for less from coal, this could be vastly disruptive. They could replace or enhance **metals** (i.e. steel, aluminum,) and **basic building materials** (i.e. cement, asphalt, rebar, roof shingles).
- ❑ Carbon also has applications in **chemicals**, and even **life sciences**.
- ❑ All of these are fast-growing, game changing uses, and can require **tremendous volumes of coal**. In some cases think 100 million tons+ per use. The US mined 725 million tons in 2017.
- ❑ A few new uses **creates a demand inflection point for the 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:

- **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 Carbon

A Vertically Integrated Coal Tech Company

Ramaco Carbon is the first pure “Coal-Tech” company. We are the **only strategic coal group** pursuing an integrated resource, technology and manufacturing based approach to incubate “**Coal to Products**”. 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 use research from the **iCAM**, coal from the **Brook Mine** and manufacture advanced carbon products.



**The “iCAM”:
Carbon
Advanced
Materials Center**



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.
- ❑ **Ramaco** has been asked to chair a White Paper from the National Coal Council to the Dept. of Energy requested by Secretary Rick Perry on “New Markets for Coal to Products”. The report will be delivered in April 2019.
- ❑ Some members are:
 - **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**
- ❑ Members of this group and other industry partners, on 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 **four** broad uses:
 - 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.**

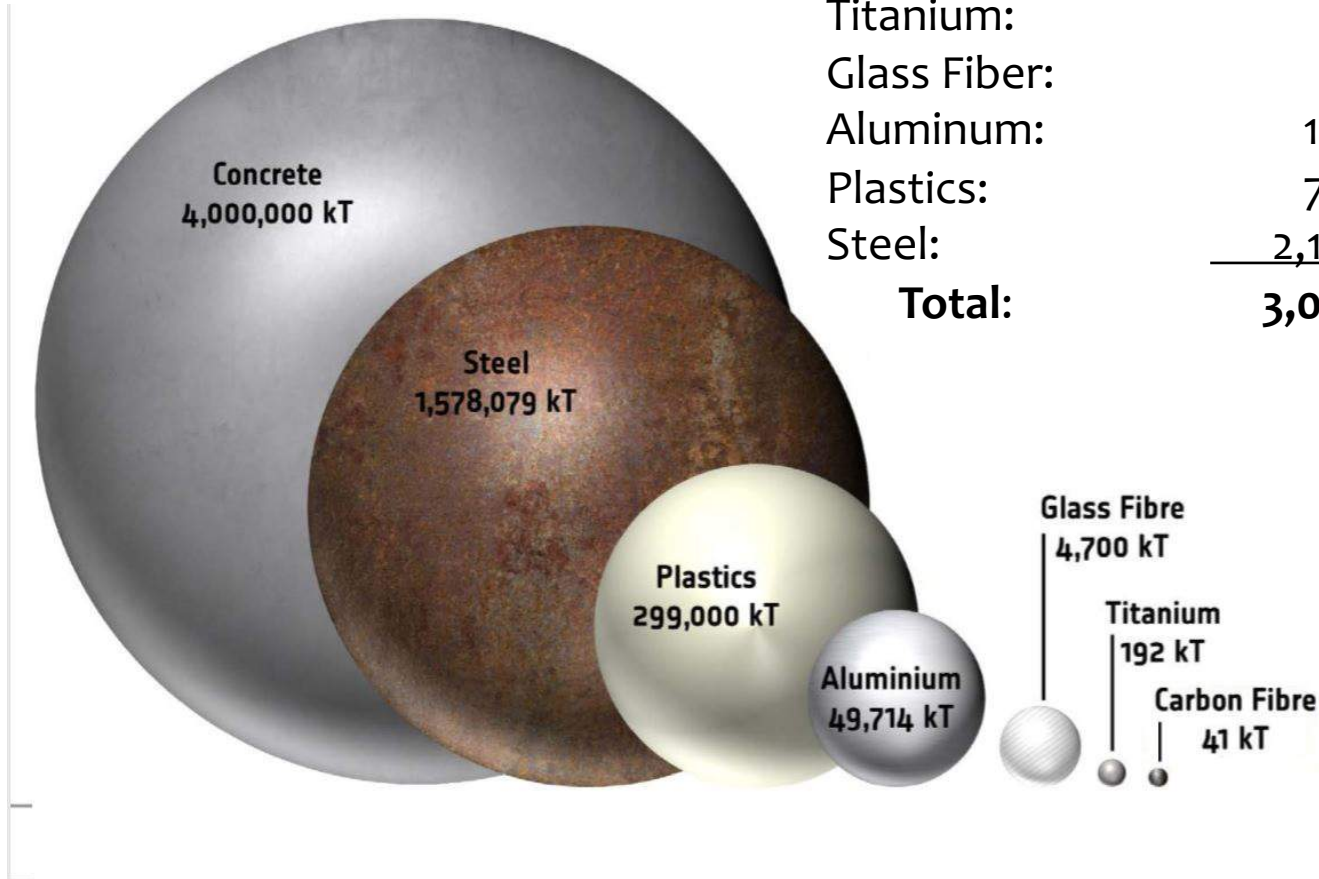
- ❑ These uses have a higher margin value proposition and can require large coal volumes.

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

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



Play Smart ...to the Advantages 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

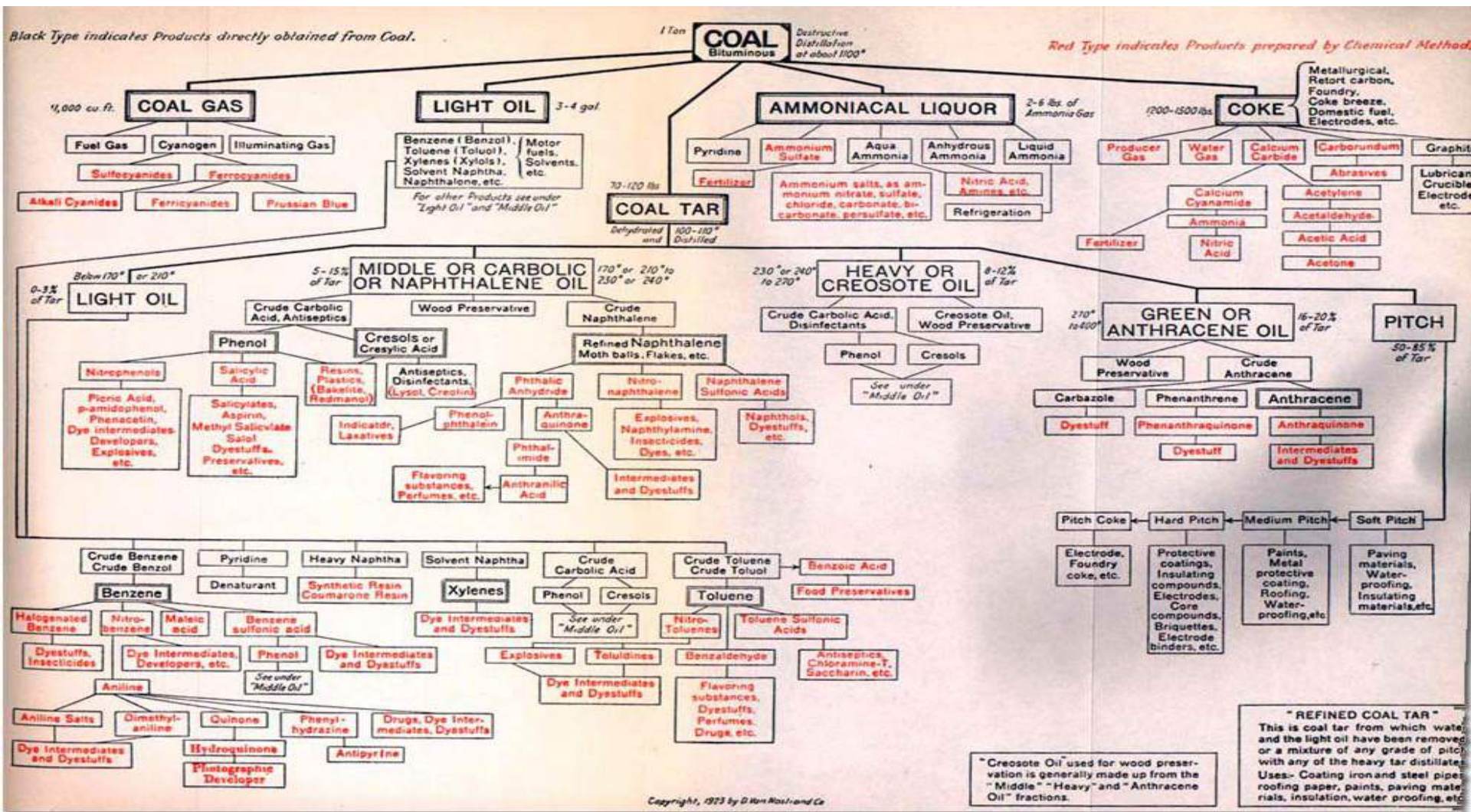
- ❑ **The “Key” to Coal’s Advantage... is cost.** Materials from coal can be made cheaper, than from petroleum.

- ❑ The way to start may actually be to go...”Back to the Future”

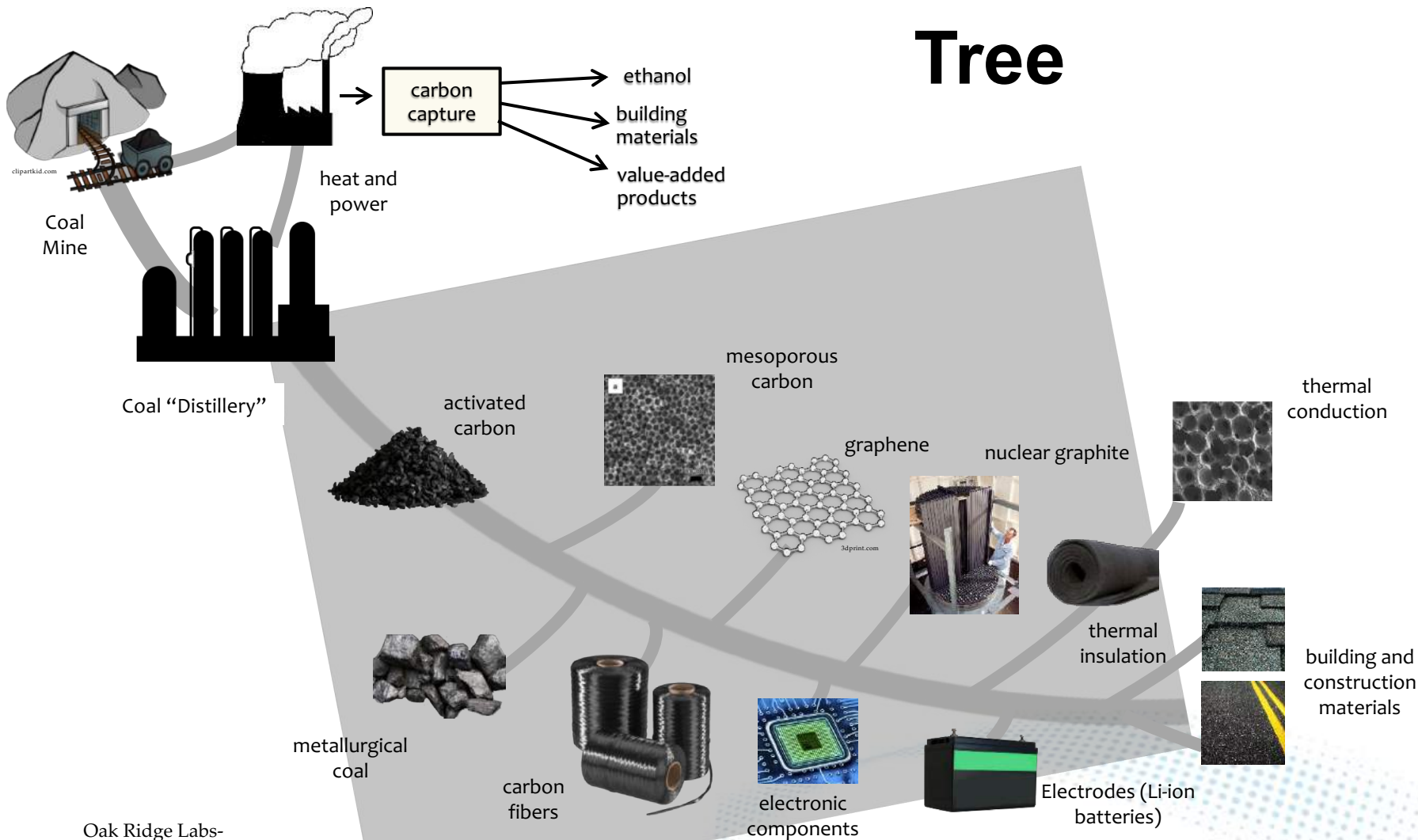
Back to the Future with Coal



Your Grand Dad's Coal Tree (circa 1923)



The New Coal Products Tree



Oak Ridge Labs-
Lara-Curzio et al. (2016)

The Margin Multiplier of Advanced Manufacturing



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

MATERIALS MANUFACTURING

**CARBON
PRODUCTS**

Carbon Fiber
& Structural
Composites
\$100,000/ton

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

Carbon
Nanomaterials
\$100,000,000/ton

**NEW
ECONOMIC
OPPORTUNITIES**
Jobs, Products, Markets

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: Carbon fiber precursor currently comes from **petroleum**. The cost is about \$15+ per pound.

If through R&D we can drop the price of carbon fiber precursor below \$5 per pound, it is game over. 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



High End
Low Volume
Hand Layup

NOW



Low Volume
Production of
Affordable Car



Low Volume
Production

NEXT



Mass Market
Appeal



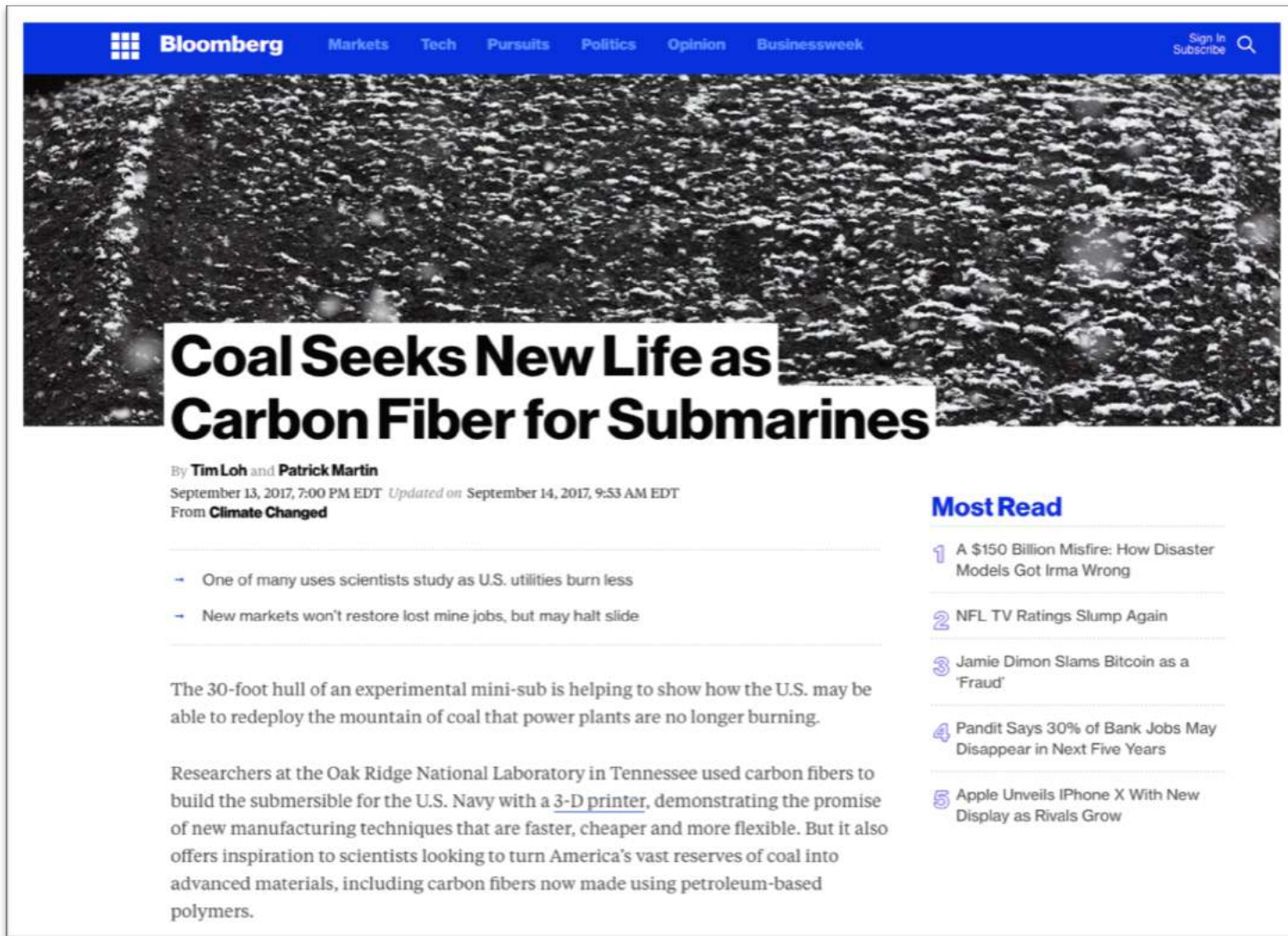
High Volume
Production

The Ramaco Carbon Fiber Family Car



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

Not Only Cars...The Revolution is Beginning



The image shows a screenshot of a Bloomberg news article. The top navigation bar includes the Bloomberg logo and links for Markets, Tech, Pursuits, Politics, Opinion, and Businessweek. The main headline is "Coal Seeks New Life as Carbon Fiber for Submarines" in large, bold black text. Below the headline, the authors are listed as "By Tim Loh and Patrick Martin" with a date of "September 13, 2017, 7:00 PM EDT" and an update date of "Updated on September 14, 2017, 9:53 AM EDT". The article is categorized as "From Climate Changed". A list of two bullet points follows: "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 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 with "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." On the right side, there is a "Most Read" section with a list of five articles, each with a numbered icon and a 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**

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- New markets won't restore lost mine jobs, but may halt slide

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Most Read

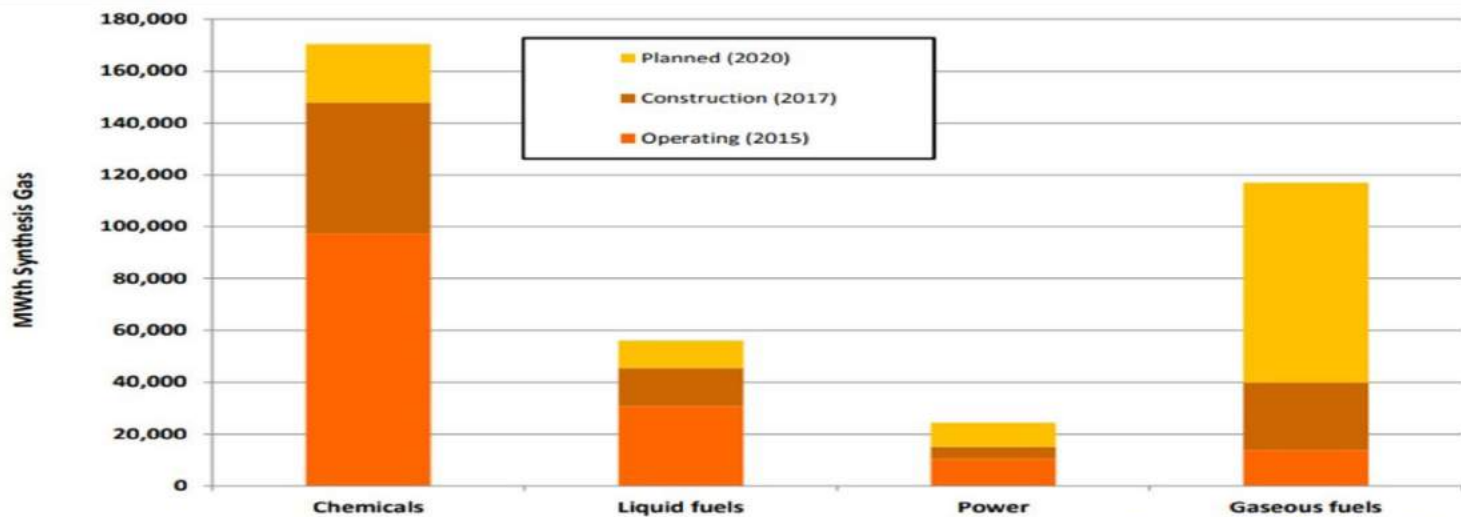
- 1 A \$150 Billion Misfire: How Disaster Models Got Irma Wrong
- 2 NFL TV Ratings Slump Again
- 3 Jamie Dimon Slams Bitcoin as a 'Fraud'
- 4 Pandit Says 30% of Bank Jobs May Disappear in Next Five Years
- 5 Apple Unveils iPhone X With New Display as Rivals Grow

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 to Advanced Carbon Manufacturing

- ❑ Coal to chemicals has been practiced for over 100 years . We are first targeting Resins for 3D Advanced manufacturing.
- ❑ 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 SR.



Source: GSTC Database, 2016

Combining 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** has taken delivery of the most advanced Carbon 3D SpeedCell printers and are currently manufacturing a wide range of products.
- ❑ End game....Make 3D resins from coal.
- ❑ This is not “smoke stack” manufacturing...

Wyoming iPark Manufacturing in 3D Printing “Farms”



Coal to 3D Printing Cycle



Wyoming iPark SpeedCell Printers



3D Printer Farm

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 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 starting with the R&D.
- ❑ **The R&D needs to focus on potential widespread Commercial applications.** Aim to use “lots of Coal” at good margins.
- ❑ Government research support is **essential** to realizing the scale of the opportunity. The DOE has accepted Coal to Products is a viable alternative to combustion
- ❑ It starts with the **lump of coal** and the **Power of Carbon**....



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