

# The Future for Coal Use in the U.S.

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## Current Trends in Energy Consumption and Coal Use in the U.S.



## Dramatic Reductions in Coal Use in Recent Years



Source: U.S. Energy Information Administration, Monthly Energy Review



#### Shale Gas Production Drives World Natural Gas Production Growth



Source: U.S. Energy Information Administration, International Energy Outlook 2016 and Annual Energy Outlook 2016



#### Changes in U.S. Electricity Generation – New Capacity

eia

U.S. utility-scale electric capacity additions and retirements (2002-16) gigawatts



Source: U.S. Energy Information Administration (Feb. 2017), Electric Power Annual and Preliminary Monthly Electric Generator Inventory



#### Employment: Electric Power Generation and Fuel Production Sectors

Table 1. Generation and Fuels Employment by Sub-Technology

	Electric Power Generation	Fuels	Total
Solar	373,807	-	373,807
Wind	101,738	-	101,738
Geothermal	5,768	-	5,768
Bioenergy/CHP	26,014	104,663	130,677
Corn Ethanol	-	28,613	28,613
Other Ethanol/Non-Woody Biomass, incl. Biodiesel	-	23,088	23,088
Woody Biomass Fuel for Energy and Cellulosic Biofuels	-	30,458	30,458
Other Biofuels	-	22,504	22,504
Low Impact Hydroelectric Generation	9,295	-	9,295
Traditional Hydropower	56,259	-	56,259
Nuclear	68,176	8,595	76,771
Coal	86,035	74,084	160,119
Natural Gas	52,125	309,993	362,118
Oil/Petroleum	12,840	502,678	515,518
Advanced Gas	36,117	-	36,117
Other Generation/Other Fuels	32,695	82,736	115,431

Taken from 2017 U.S. Energy and Employment Report, https://www.energy.gov/downloads/2017-us-energy-and-employment-report



## Summary of Current Trends

- Dramatic rise in natural gas production due to development of hydraulic fracturing technology
  - has significantly reduced coal use
  - Ied to overall reductions in CO<sub>2</sub> emissions
- Substantial increases in solar and wind generating capacity has led to
  - shift to greater use of low-C renewable energy
  - unprecedented employment growth in these two industries
- Future of traditional coal-fired power generation is unclear



## Future Coal Use – Consideration of Other Potential Uses for Coal



### Alternative Uses for Coal

- Consideration of coal as high-value raw material vs. use for energy content
  - Potential for development of "coal refineries"
- High-value Coal Products
  - Production volumes likely reduced relative to electricity generation
- Examples of potential products
  - Commodity chemicals
  - Rare earth elements
  - Carbon fiber
  - Carbon electrodes
  - Graphene
  - Many others

Will briefly discuss in today's presentation







#### Rare Earth Element Recovery from Coal and Coal Byproducts



#### Background – Rare Earth Elements (REE)

- Key elements used in materials for
  - Magnets, batteries, computers, electronics, autos, military/defense, many others
- Market dominated by China (95% in 2010)
- Currently, U.S. relies primarily on imports



Courtesy: Mary Anne Alvin U.S. DOE/NETL



#### Uses - Rare Earth Elements (REE)





#### Uses - Rare Earth Elements (REE)

#### Rare Earth Elements in Smartphones

REE in different parts of a phone. Other scarce elements indicated within brackets.

#### SPEAKERS

Praseodymium Neodymium Gadolinium

Courtesy: Edgar Lara-Curzio Oak Ridge National Lab

#### 

Yttrium Europium Gadolinium Terbium

CAMERA Lanthanum Yttrium CIRCUITRY Neodymium Dysprosium (Tantalum) BATTERY Lanthanum Praseodymium (Lithium)

VIBRATION Neodymium (Tungsten)

http://www.insightsonindia.com

http://cen.acs.org/



#### Current Status for REE Recovery from Coal and Coal Products

- Study by DOE/NETL indicates U.S. coal and coal byproducts contain ~11 million metric tonnes of REEs
- 3 researchers reported on progress at 2017 Clearwater Conference\*
  - University of North Dakota (Laudal et al.)
    - surveyed regional coals and associated sediments and REE ranged from 150-200 pm for sediments to 300-600 ppm for coals
  - University of Kentucky & Virginia Tech (Honaker et al.)
    - 60-85% recovery of REEs, depending upon which portion of the mined coal material was used
  - University of Wyoming (Huang et al.)
    - REE's were concentrated in their process from 0.05% in ash to over 10% in products
- U.S. DOE announced \$4 million in 2017 for 9 new REE research projects
- Upcoming 2018 Clearwater Conference\*\* two sessions with 10 research papers on REE recovery

\*42<sup>nd</sup> International Clean Energy Conference, June 11-15, 2017, Clearwater, FL \*\*43<sup>rd</sup> International Clean Energy Conference, June 3-7, 2018, Clearwater, FL



#### Carbon Fiber Production from Coal







## **Carbon Fiber Production**

- Primary precursor material for carbon fiber(CF) production (90-95%) is Polyacrylonitrile (PAN)
- Primary uses are in carbon composite materials for:
  - Aerospace applications (B787, A350, others)
  - Sporting goods
  - Wind turbine blades
  - High-end automobiles
  - Specialty applications (medical, structural, etc.)
  - Rough guide "5 and 5"
- Main barrier to broader utilization is <u>cost</u>



















### Market for Low-Cost Carbon Fiber

- Total 2016 worldwide production of Carbon Fiber – 200 million lbs
- Forecasted growth of automotive industry by 2023 280 million Ibs additional
  - US automobile production 2016 12 million
  - Example: Ford F-150 truck, 1 million per year @ 20 lbs => 20 million lbs
- Current fiber is expensive \$10-25/lb
- Our target is <\$5/lb</p>





Market info from





### **Opportunities for Cost Reduction**

Overall process modifications – difficult to achieve significant reductions



Direct cost impact by identifying lower cost precursors and increasing yield from precursors



#### Processing Coal to Produce Carbon Fiber





#### **Commercial Coal Tar Pitch Fiber**

MITSUBISHI CHEMICAL CARBON FIBER AND COMPOSITES

CARBON FIBER / COMPOSITE MATERIALS / ABOUT / NEWS / CONTACT US

#### SELECTOR GUIDE



DIALEAD is a high performance coal tar pitch based carbon fiber, available in a large range of product formats from low to ultra high tensile modulus grades.



High and Ultra High Tensile Modulus grades suitable for prepregging, filament winding, and weaving. Chopped Fiber

Widely used in thermoplastic and thermosetting resins to improve electric and thermal conductivity and mechanical strength.

#### Milled Fiber

Widley used to improve elctric and thermal conductivity in thermoplastic and thermosetting matrices.

#### Fabric

Various bi-directional and UD cloths are available. All continuous fiber grade can be woven.



We offer various resin systems in unidirectional carbon-fiber-woven cloth impregnated forms.

#### http://mccfc.com/pitch-fiber/



## Coal to Carbon Program at the University of Utah & Kentucky\*

Explore viability of Utah coals for carbon fiber (CF) production

- Will expand to coals from other regions with additional funding
- Investigate avenues for reducing cost for producing CF
  - Facilitates entry into automotive and other consumer markets
- Investigate methods for tailoring fiber properties based on coal chemistry and pitch/fiber production methodologies
- Help develop a new coal-based carbon composites manufacturing industry (with help from UAMMI)
  - To assist Utah and other regions adversely impacted by changes in the coal economy

\*funded by Dept. of Commerce/Economic Development Administration (EDA)



#### UT/KY Coal to Carbon Fiber Program





### Summary – Coal to Carbon Fiber

- Opportunities exist for carbon fiber as a high-value coal product
- Carbon fiber market can expand to accommodate increased production
  - Automotive, wind turbine blades, etc. key will be cost
    - 10% penetration of automotive market => triple current CF production
- Economics for carbon fiber production improved through coproduction of other coal products
  - e.g., rare earths, carbon electrodes, commodity chemicals, activated carbon, etc.
  - Utah/Kentucky/UAMMI program
    - Have successfully spun good quality CF from Utah coal
      - Continuing CF optimization to increase quality and identify production improvements
    - Very high interest from many coal-producing states
    - Interest from carbon composite and automotive industries
    - Exploring opportunities to scale-up bench-scale efforts



## **Concluding Comments**

- Significant decrease in coal utilization in the U.S. due to
  - extensive shale gas production
  - increases in solar and wind generating capacity
  - concerns over global carbon emissions
- Need to shift our perspectives on coal
  - Not just an energy resource
  - Great potential as a raw material for higher-value products
  - May provide additional economic opportunities for distressed coal-mining regions in the U.S.



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