Coal's Bright Future

Unlocking New Markets with Novel Technologies

H Quest Vanguard, Inc.

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United States Energy Association

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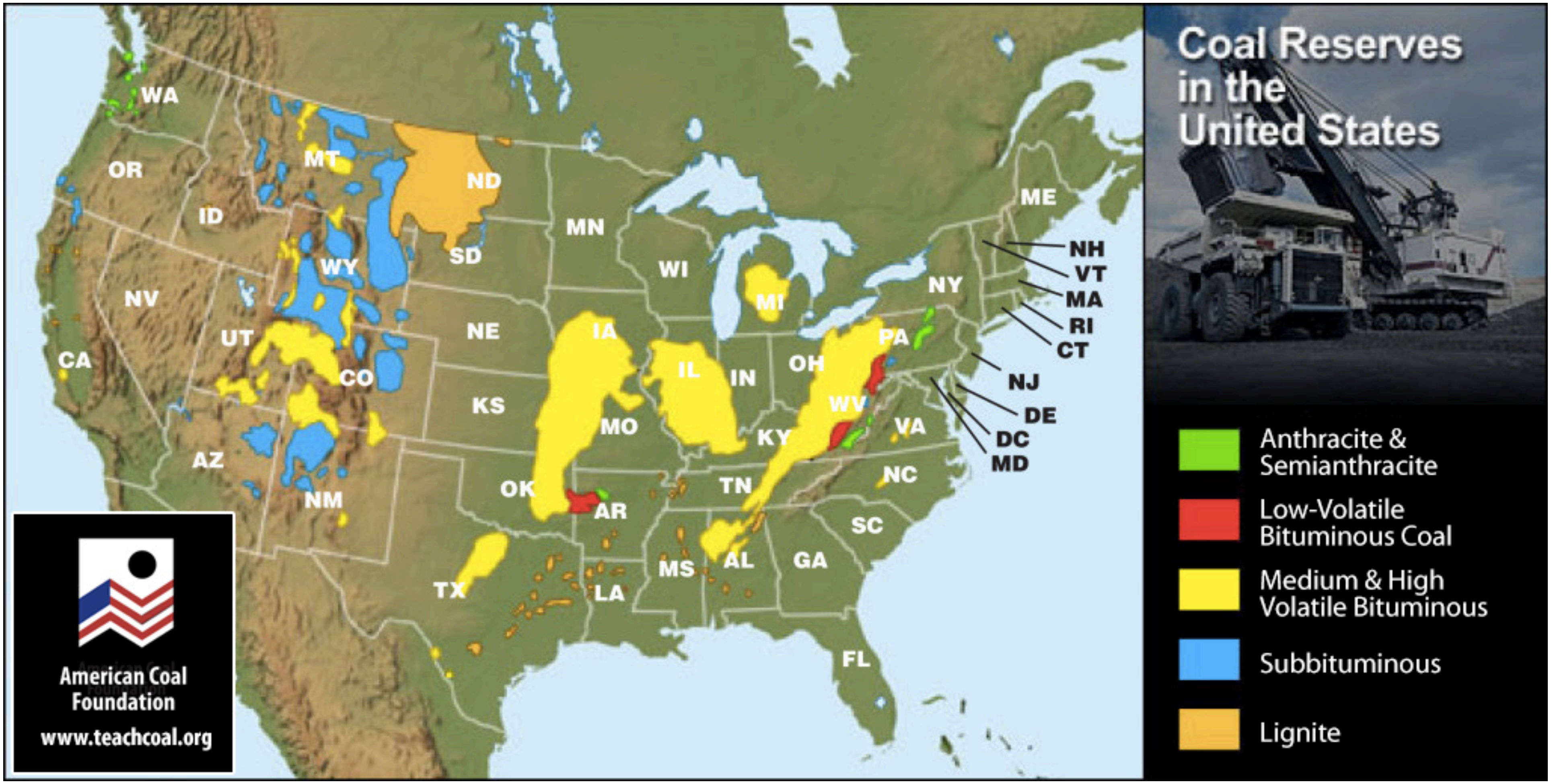
Quest


U.S. public holds a dim view of American coal.
To most people, coal is synonymous with *electricity at the lowest cost*

Coal is United States' unmatched wealth



United States proven coal reserves: 255 billion tons

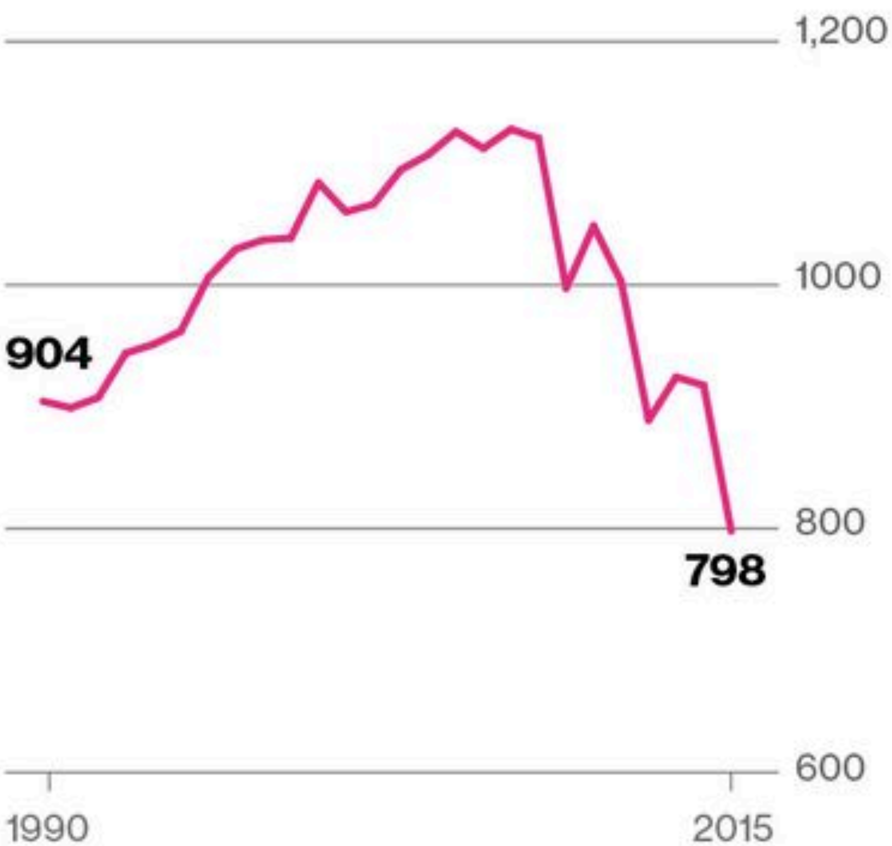
(> 25% of the world's)

Coal Economy in Decline

Reduced demand and increased mechanization continue to reduce headcount.

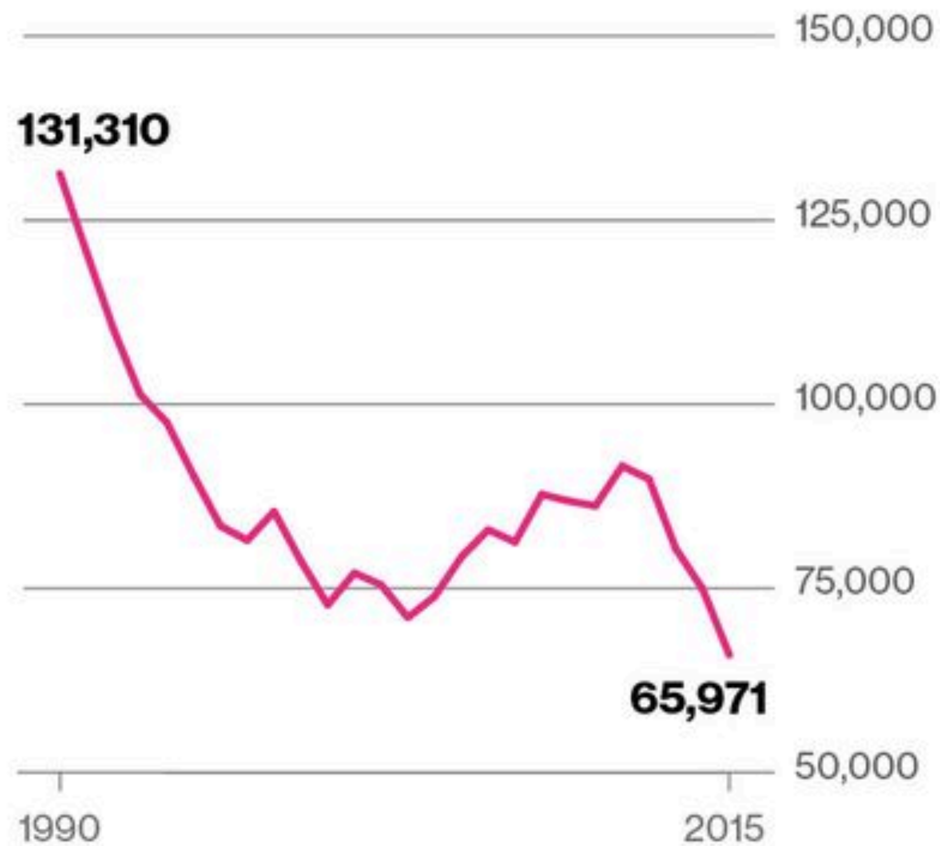
Consumption

Total U.S. coal consumption, million short tons



Employment

Total U.S. coal mining jobs*



*Includes all employees engaged in production, processing, development, maintenance, repair shop, or yard work at mining operations, including office workers

Source: U.S. Energy Information Administration

Bloomberg

Can the coal jobs be recovered?

Coal employment "can't be brought back to where it was before the election of Barack Obama."

Robert Murray, CEO of Murray Energy

"I absolutely have no idea how they could take steps to bring back coal to the levels that we saw in 2008,"

John Deskins, Director of the Bureau of Business and Economic Research at West Virginia University

Industrial Revolution:

- Began 2 centuries ago in Britain
- Changed the course of economic history

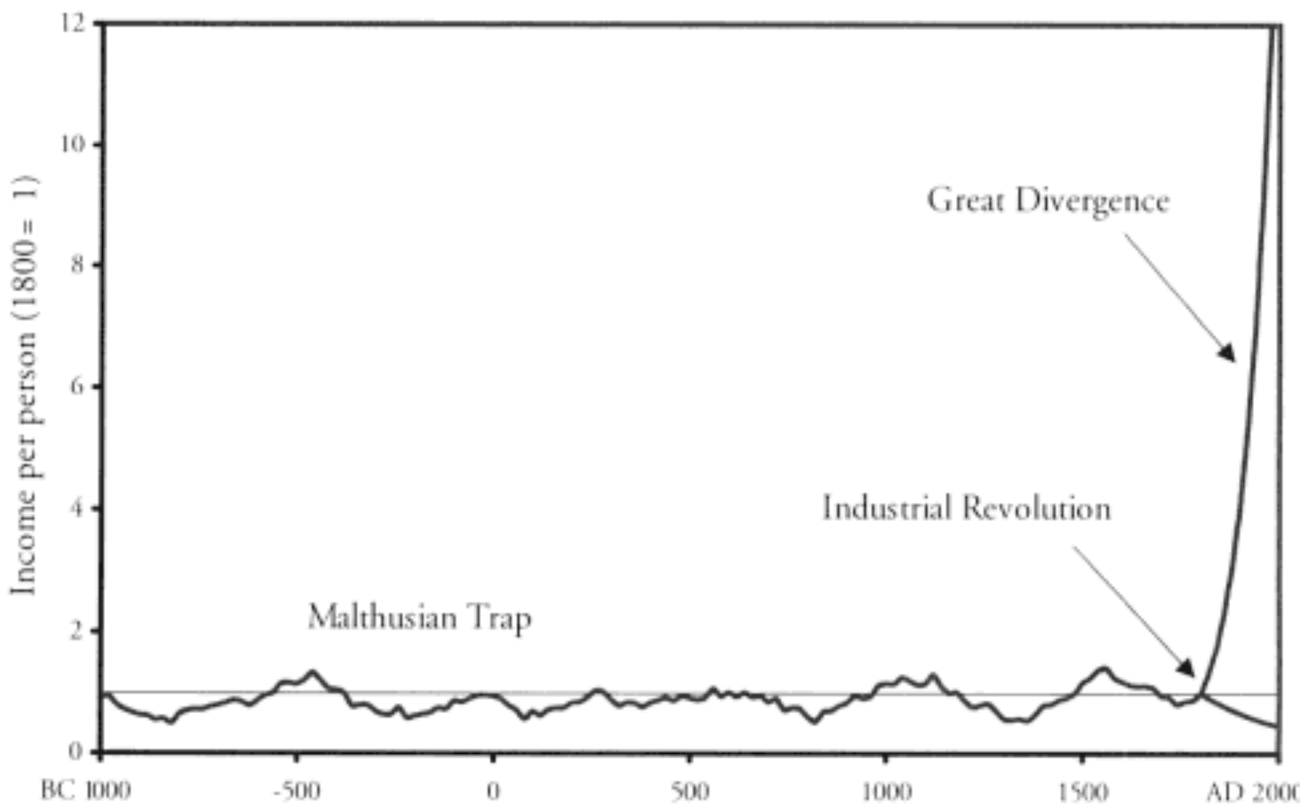
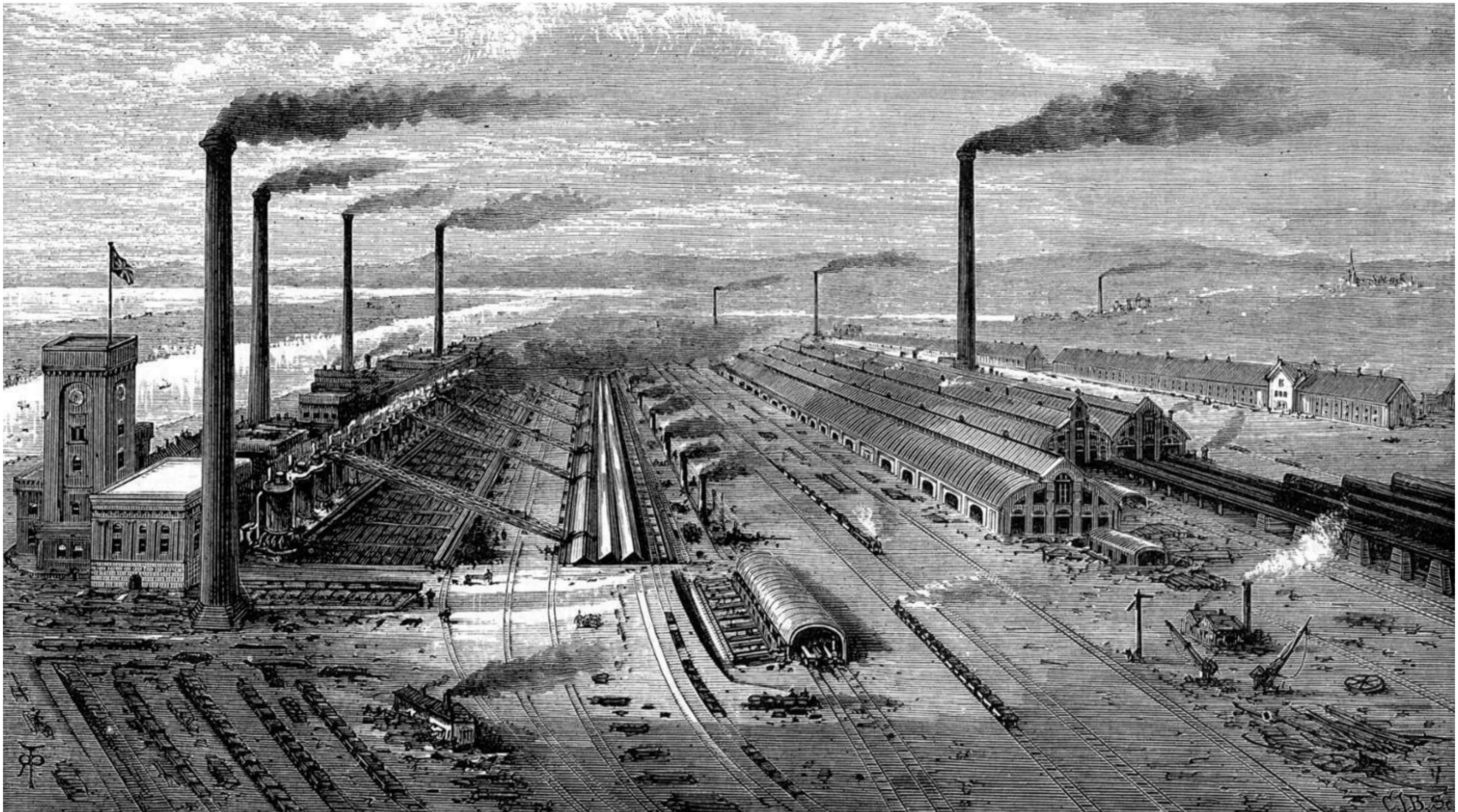


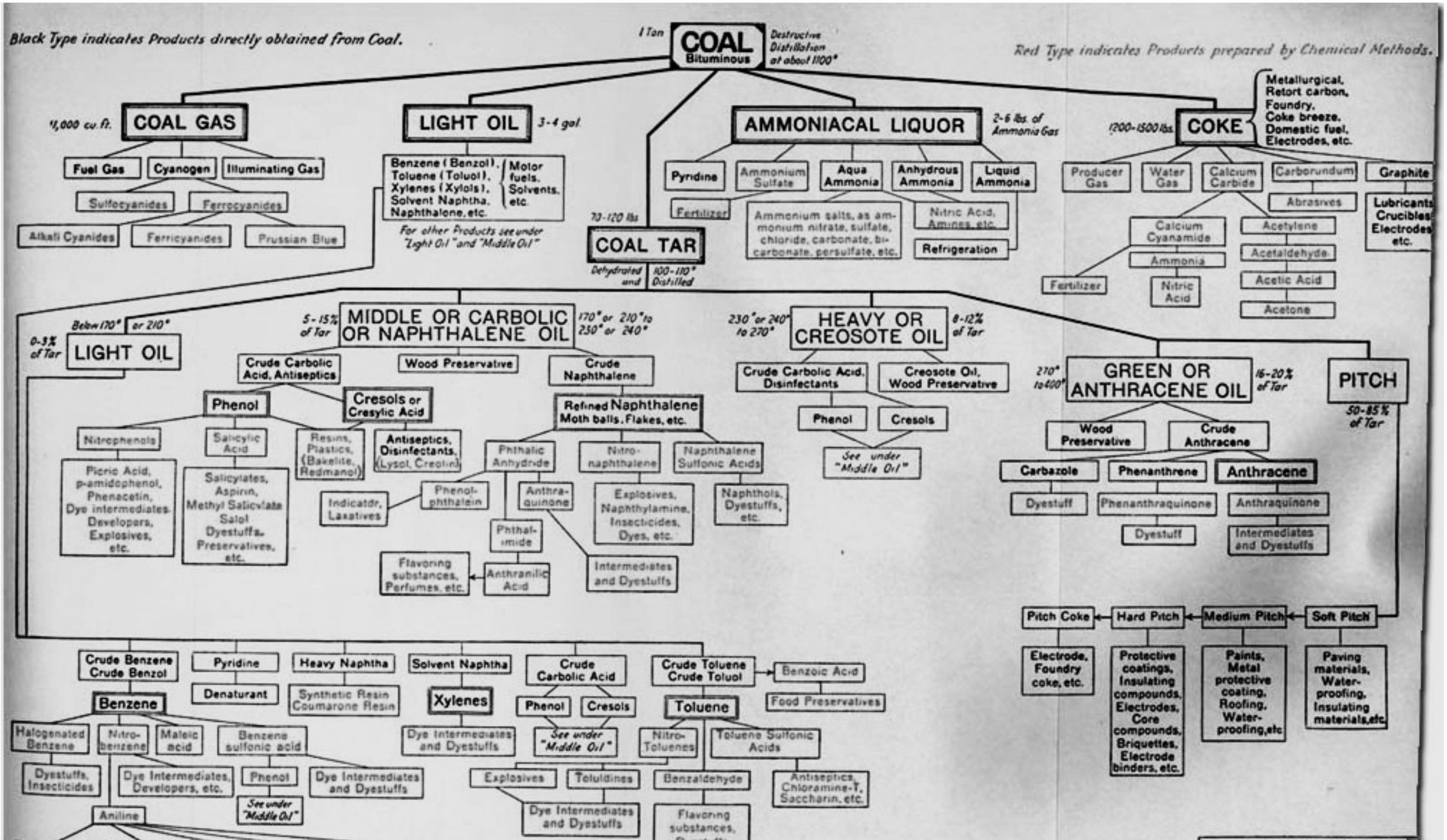
Figure 1.1 World economic history in one picture. Incomes rose sharply in many countries after 1800 but declined in others.

Gregory Clark (2007) A Farewell to Alms: A Brief Economic History of the World. Princeton University Press.



The two drivers of Industrial Revolution:

- Rapid technological development
- Ready access to coal

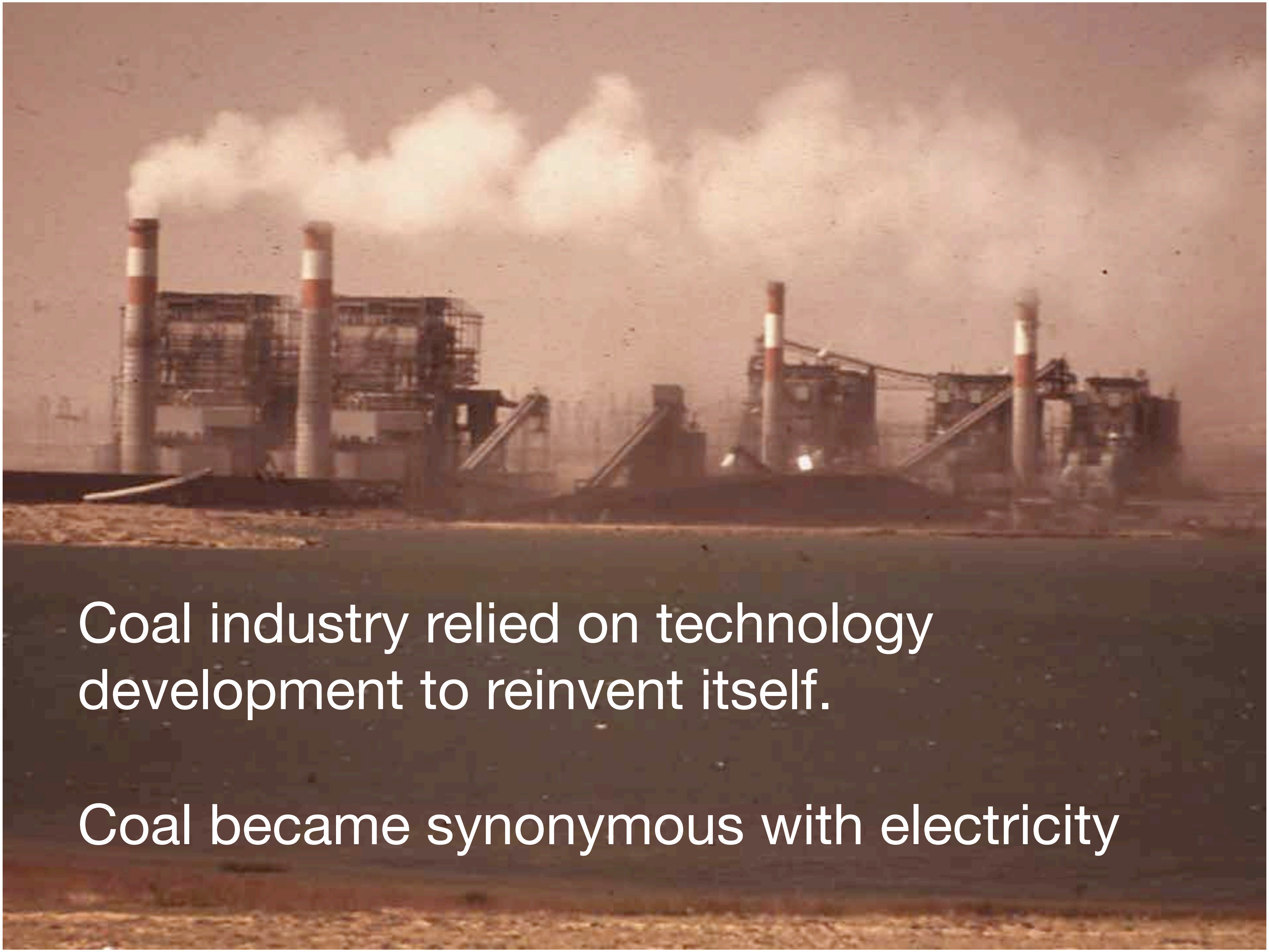


Coal: a foundation for economic development

- A lot more than a cheap and readily available energy source
- A universal source of emerging materials and chemicals

Cheap oil displaced coal in the 20th century

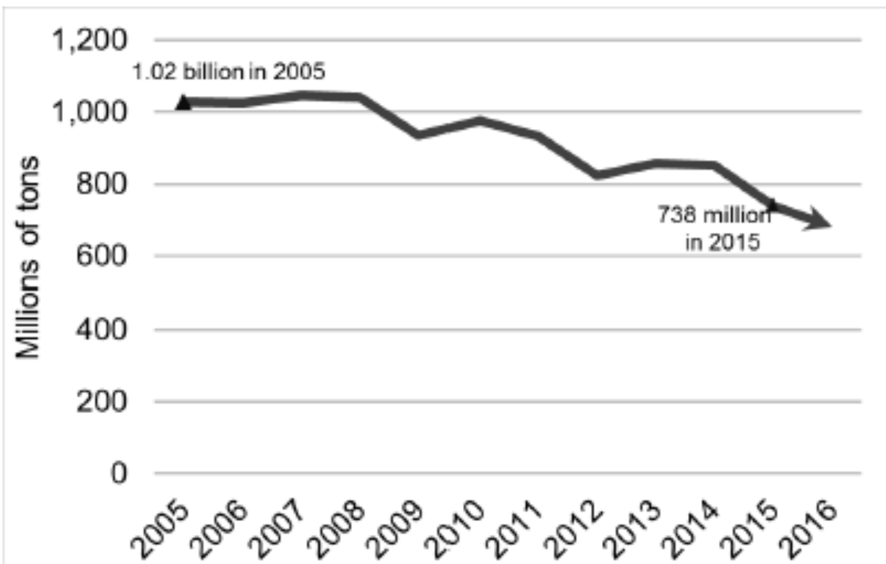
- Became the primary source of fuels, chemicals and materials
- Was easier and cheaper to extract, convert, distill and refine


Coal industry relied on technology development to reinvent itself.
Coal became synonymous with electricity

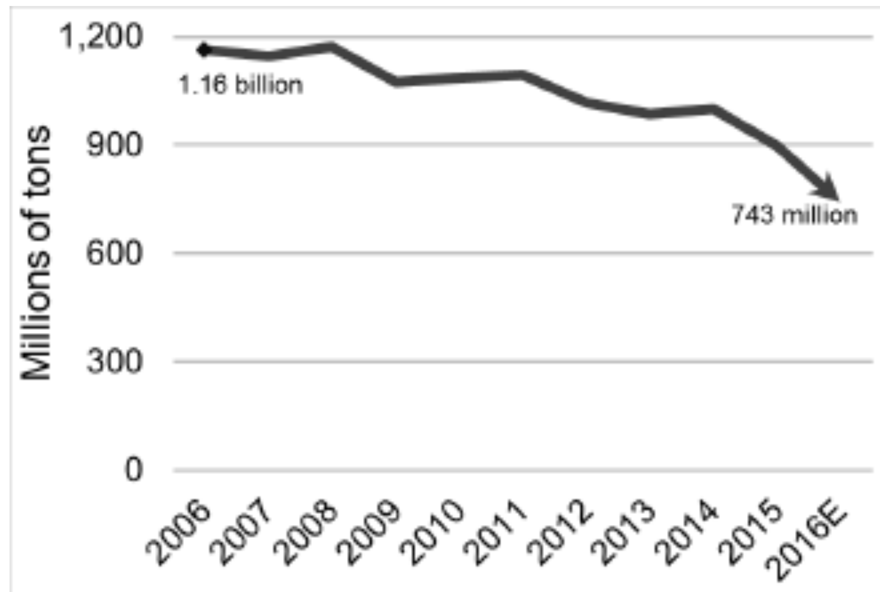
The electricity coal market is in decline

Coal desperately needs new markets

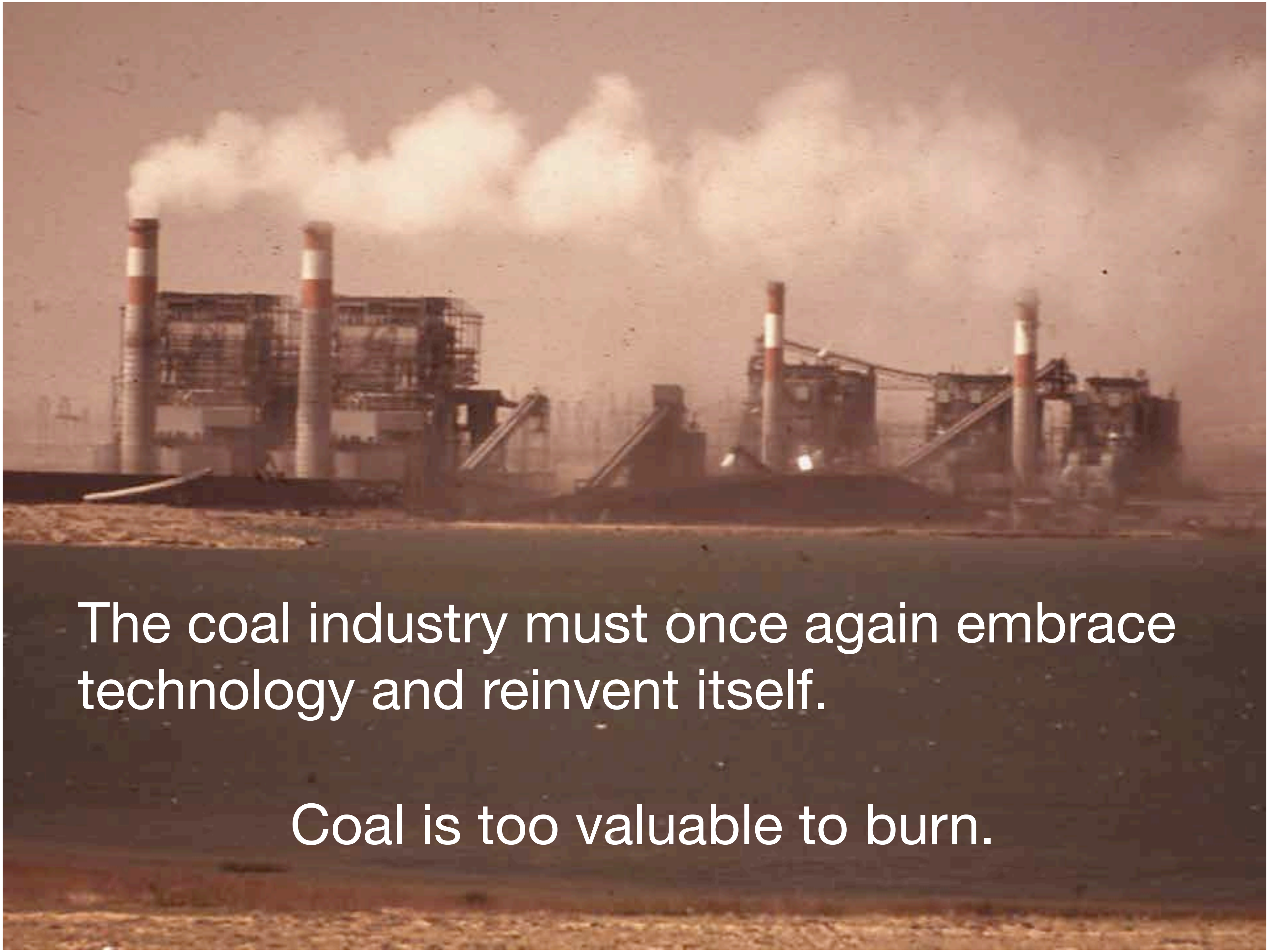
U.S. Coal Consumption for Electricity from 2005 to 2016

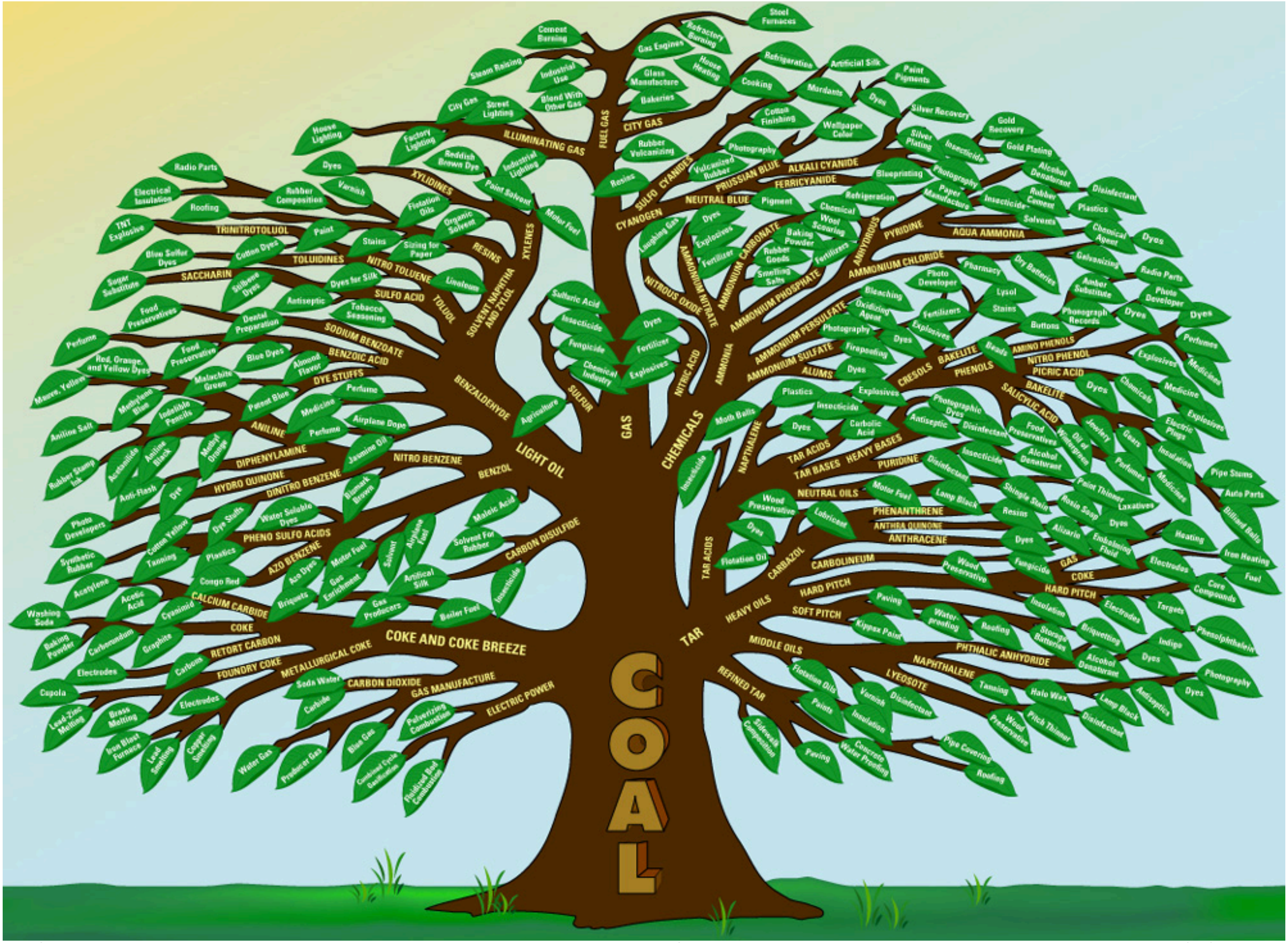


U.S. Coal Production from 2005 to 2016



Only a game-changing technology can create them at relevant scale.


The coal industry must once again embrace technology and reinvent itself.
Coal is too valuable to burn.


COAL
GAS
CHEMICALS
TAR
LIGHT OIL
COKE AND COKE BREEZE
FUEL GAS
CITY GAS
ILLUMINATING GAS
CYANOGEN
SULFO CYANIDES
PRUSSIAN BLUE
ALKALI CYANIDE
FERRICYANIDE
NEUTRAL BLUE
NITROUS OXIDE
AMMONIUM NITRATE
AMMONIUM CARBONATE
ANHYDROUS
PYRIDINE
AQUA AMMONIA
AMMONIUM CHLORIDE
AMMONIUM PHOSPHATE
AMMONIUM PERSULFATE
AMMONIUM SULFATE
ALUMS
AMMONIA
NITRIC ACID
SULFUR
CRESOLS
BAKELITE
PHENOLS
AMINO PHENOLS
NITRO PHENOL
PICRIC ACID
SALICYLIC ACID
NAPTHALENE
TAR ACIDS
TAR BASES
HEAVY BASES
PURIDINE
NEUTRAL OILS
PHENANTHRENE
ANTHRA QUINONE
ANTHRACENE
CARBOLINEUM
CARBAZOL
HARD PITCH
SOFT PITCH
HEAVY OILS
MIDDLE OILS
REFINED TAR
PHTHALIC ANHYDRIDE
NAPHTHALENE
LYEOSOTE
GAS
COKE
XYLIDINES
XYLENES
RESINS
SOLVENT NAPHTHA AND ZYLOL
TOLUOL
TRINITROTOLUOL
TOLUIDINES
NITRO TOLUENE
SULFO ACID
SACCHARIN
SODIUM BENZOATE
BENZOIC ACID
DYE STUFFS
BENZALDEHYDE
BENZOL
ANILINE
DIPHENYLAMINE
HYDRO QUINONE
DINITRO BENZENE
NITRO BENZENE
PHENO SULFO ACIDS
AZO BENZENE
CARBON DISULFIDE
CALCIUM CARBIDE
COKE
RETORT CARBON
FOUNDRY COKE
METALLURGICAL COKE
CARBON DIOXIDE
GAS MANUFACTURE
ELECTRIC POWER
Steel Furnaces
Cement Burning
Refractory Burning
Gas Engines
House Heating
Glass Manufacture
Bakeries
Steam Raising
Industrial Use
Blend With Other Gas
City Gas
Street Lighting
Refrigeration
Artificial Silk
Paint Pigments
Cooking
Mordants
Dyes
Silver Recovery
Cotton Finishing
Wallpaper Color
Gold Recovery
Gold Plating
Silver Plating
Insecticide
Photography
Rubber Vulcanizing
Vulcanized Rubber
Resins
Blueprinting
Paper Manufacture
Alcohol Denaturant
Disinfectant
Pigment
Refrigeration
Rubber Cement
Solvents
Plastics
House Lighting
Factory Lighting
Reddish Brown Dye
Industrial Lighting
Paint Solvent
Motor Fuel
Radio Parts
Electrical Insulation
Rubber Composition
Varnish
Roofing
Flotation Oils
Organic Solvent
TNT Explosive
Paint
Stains
Sizing for Paper
Blue Sulfur Dyes
Cotton Dyes
Linoleum
Sugar Substitute
Stilbene Dyes
Dyes for Silk
Antiseptic
Tobacco Seasoning
Food Preservatives
Dental Preparation
Perfume
Red, Orange, and Yellow Dyes
Food Preservative
Blue Dyes
Almond Flavor
Malachite Green
Mauve, Yellow
Methylene Blue
Indelible Pencils
Patent Blue
Medicine
Airplane Dope
Aniline Salt
Aniline Black
Acetanilide
Methyl Orange
Jasmine Oil
Rubber Stamp Ink
Anti-Flash
Dye
Bismark Brown
Photo Developers
Cotton Yellow
Dye Stuffs
Water Soluble Dyes
Maleic Acid
Synthetic Rubber
Tanning
Plastics
Solvent
Airplane Fuel
Solvent For Rubber
Acetylene
Congo Red
Azo Dyes
Motor Fuel
Gas Enrichment
Artificial Silk
Insecticide
Washing Soda
Acetic Acid
Cyanimid
Briquets
Gas Producers
Boiler Fuel
Baking Powder
Carborundum
Graphite
Electrodes
Carbons
Soda Water
Carbide
Cupola
Lead-Zinc Melting
Brass Melting
Iron Blast Furnace
Lead Smelting
Copper Smelting
Water Gas
Producer Gas
Blue Gas
Pulverizing Combustion
Combined Cycle Gasification
Fluidized Bed Combustion
Sulfuric Acid
Insecticide
Fungicide
Chemical Industry
Fertilizer
Explosives
Agriculture
Laughing Gas
Explosives
Fertilizer
Baking Powder
Wool Scouring
Chemical
Rubber Goods
Smelting Salts
Fertilizers
Photo Developer
Bleaching
Oxidizing Agent
Photography
Fireproofing
Pharmacy
Dry Batteries
Lysol
Stains
Buttons
Phonograph Records
Amber Substitute
Galvanizing
Chemical Agent
Radio Parts
Photo Developer
Perfumes
Medicines
Explosives
Chemicals
Medicine
Explosives
Electric Plugs
Insulation
Plastics
Insecticide
Carbolic Acid
Moth Balls
Photographic Dyes
Antiseptic
Disinfectant
Food Preservatives
Wintergreen
Oil of
Jewelry
Gears
Perfumes
Alcohol Denaturant
Paint Thinner
Laxatives
Medicines
Pipe Stems
Auto Parts
Billiard Balls
Wood Preservative
Lubricant
Motor Fuel
Lamp Black
Shingle Stain
Resins
Rosin Soap
Embalming Fluid
Alizarin
Heating
Iron Heating
Fuel
Flotation Oil
Fungicide
Electrodes
Core Compounds
Paving
Water-proofing
Kippax Paint
Roofing
Insulation
Storage Batteries
Briquetting
Targets
Indigo
Phenolphthalein
Flotation Oils
Paints
Varnish
Disinfectant
Tanning
Halo Wax
Alcohol Denaturant
Antiseptics
Lamp Black
Photography
Sidewalk Composition
Paving
Concrete Water Proofing
Pipe Covering
Roofing
Wood Preservative
Pitch Thinner
Disinfectant

Coal conversion: strategic initiative in China

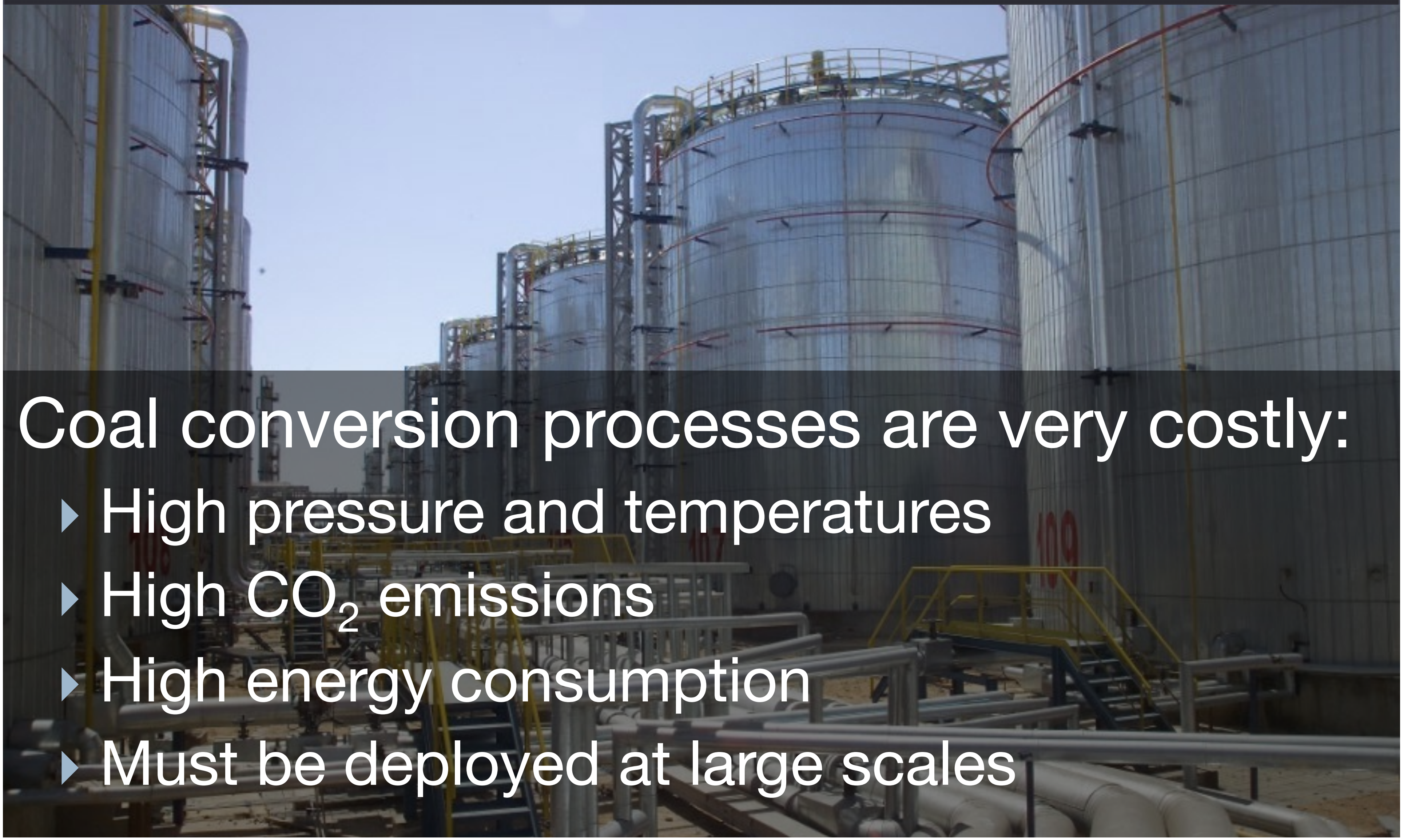
NEW CHINA CTO/MTO PLANTS, '000 TONNES/YEAR

Company	Location	Facitility	Ethylene Capacity	Downstream Capactiy	Start-up
Shenhua Yulin	Shenmu, Shaanxi	MTO	300	PE (300)	Dec 2015
Inner Mongolia, ChinaCoal Mengda New Energy & Chemical Industry	Erdos, Inner Mongolia	CTO	300	HDPE/ LLDPE (300)	Apr 2016
Shenhua Xinjiang	Urumqi, Xinjiang	CTO	320	LDPE (320)	Late Q2 2016
Qinghai Salt Lake Industry	Golmud, Qinghai	CTO	160	PVC (300)	Q3 2016
Fund (Changzhou) Energy & Chemical*	Changzhou, Jiangsu	MTO	165		Q3 2016
Jiangsu Sailboat Petrochemical	Lianyungang, Jiangsu	MTO	370	EVA/LLDPE (300), EO (180), MEG (20)	Q4 2016
Total			1,615		

NOTE: *Will supply to Changzhou Dohow's new 300,000 tonne/year styrene plant

Source: ICIS Chemical Business

Coal conversion has a problem –



Coal conversion processes are very costly:

- High pressure and temperatures
- High CO_2 emissions
- High energy consumption
- Must be deployed at large scales

Poor environmental footprint
High capital & operating costs.

A typical Fischer-Tropsch plant:

- CAPEX: >$75,000+ per barrel day of production
- Cost: ~$4B for a 50,000 bpd plant
- CO_2 emissions: > 700 kgCO_2 / barrel
- 75% of CAPEX due to gasification

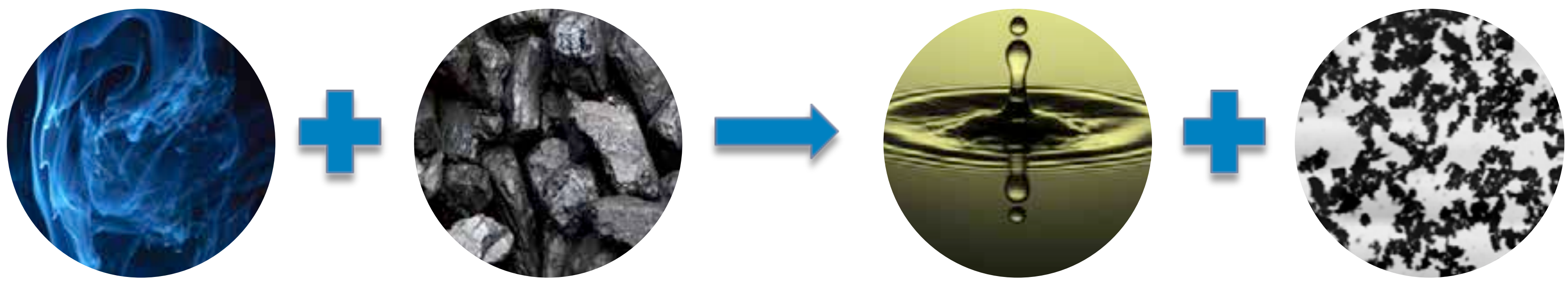
New generation of technologies are needed

Requirements:

- CAPEX: < $20,000 / barrel day of production
- Viable at smaller scales (10,000- bpd)
- Direct conversion to value-added products
- Reduced greenhouse gas profile

Wave Liquefaction™ is game changing

It cleanly and efficiently combines **coal** and **natural gas** to produce crude oil, fuels, chemicals, and carbon materials.



Natural Gas | Domestic Coal | Crude Oil | Carbon Materials

Originally developed with **DARPA** funding at a **DOE** national lab for production of jet fuel from coal for the US Air Force.

Will create **new markets for coal** impacting advanced manufacturing, national security, energy, and infrastructure.

Wave Liquefaction™ process:

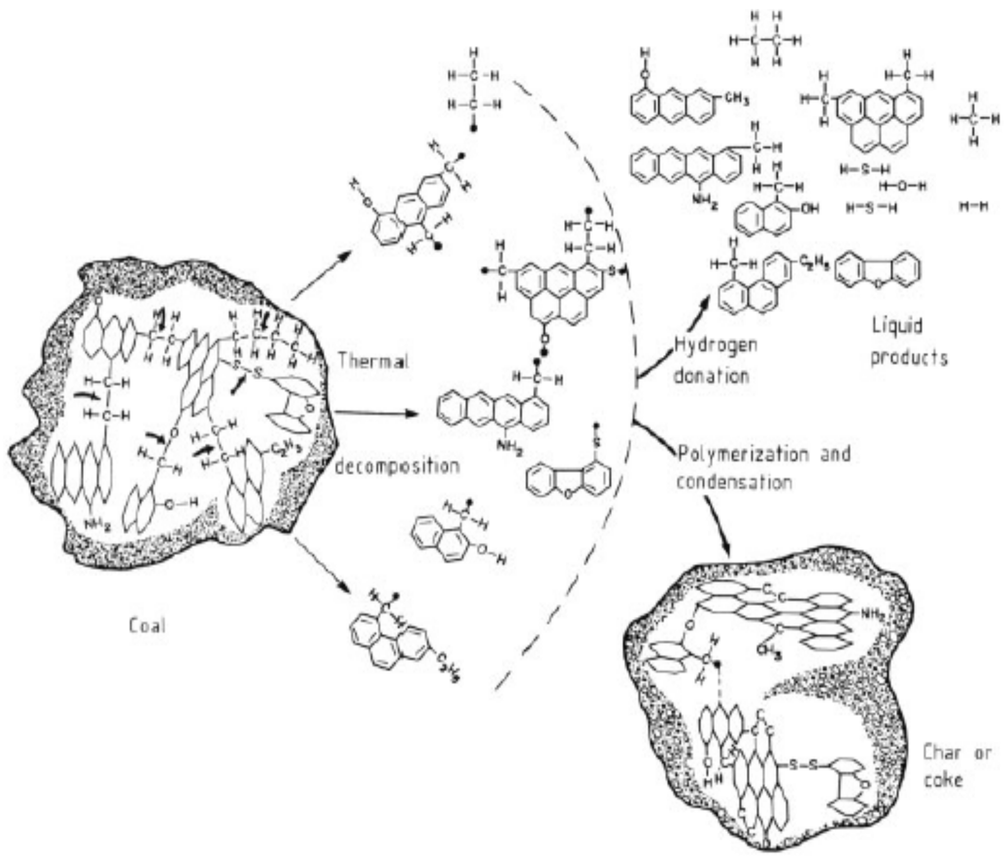
Environmentally responsible, economically attractive coal conversion technology.

Key advantages :

- economically competitive (\$30-\$45/bbl)
- low capital requirements (\$15K/bpd)
- virtually zero CO_2 emissions
- no water consumption
- very high feed and product flexibility
- direct conversion of domestic coal to crude oil, chemicals, and materials.

Principles of Direct Coal Liquefaction

- Breaking down coal's macromolecular structure
- Increasing hydrogen content of the liquid products



High pressures and temperatures → High CAPEX and OPEX
Need for hydrogen production → High CO_2 emissions and water consumption

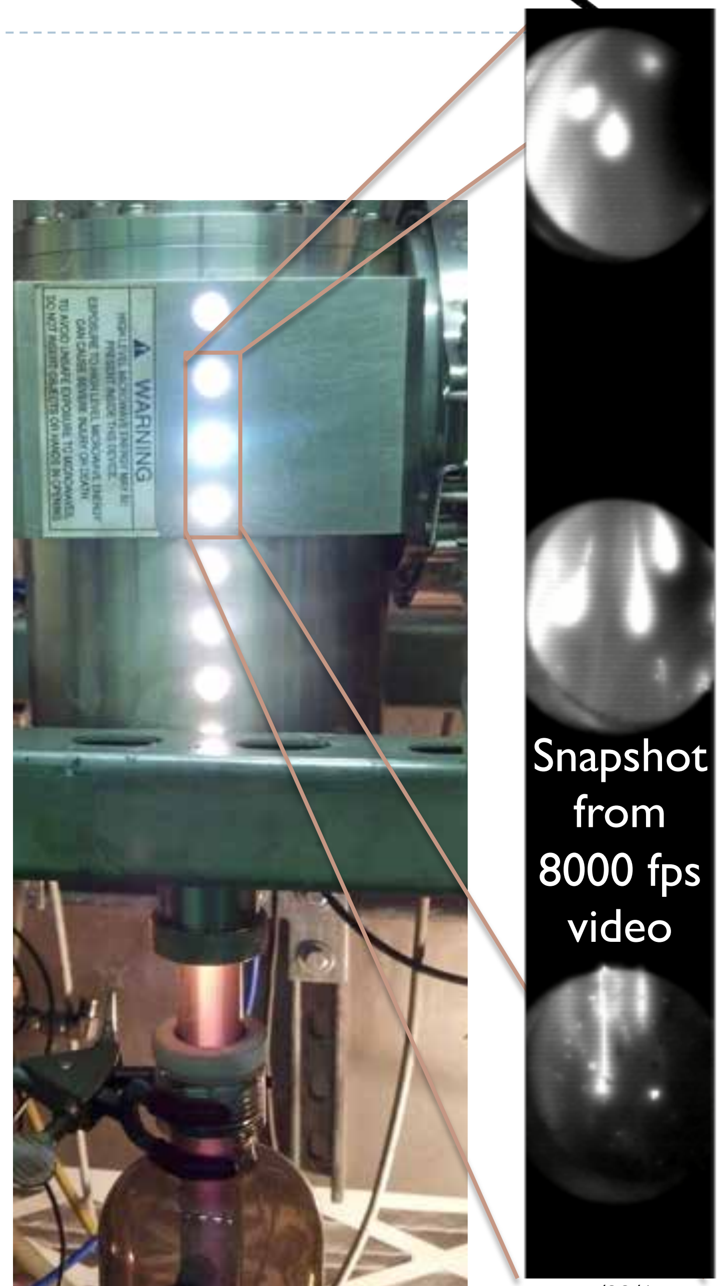
Wave Liquefaction™ takes a different approach…

Microwave/RF energy creates intense reaction zones localized around solid particles.

Bulk temperatures remain below pyrolytic temperatures, while coal particles within fractions of a second are rapidly heated to >1200 °C.

Emergent process advantages:

- High (80%) thermal efficiencies
- Suppression of secondary reactions
  - High liquid yields (> 60%)
  - Low gas yields (<< 5%)
- Short residence times (< 1 sec)
- High throughput
- Small form-factor



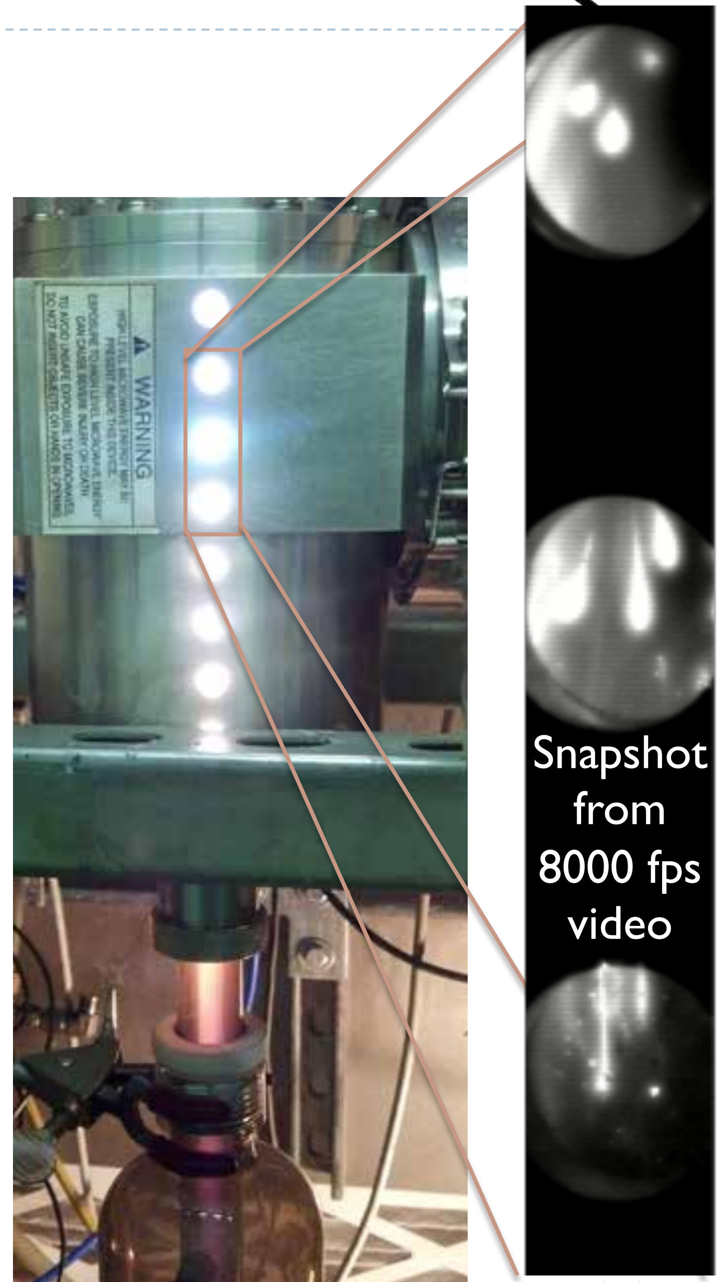
…aided by direct methane activation

Low-energy process gas ionization promotes direct activation of methane, which results in:

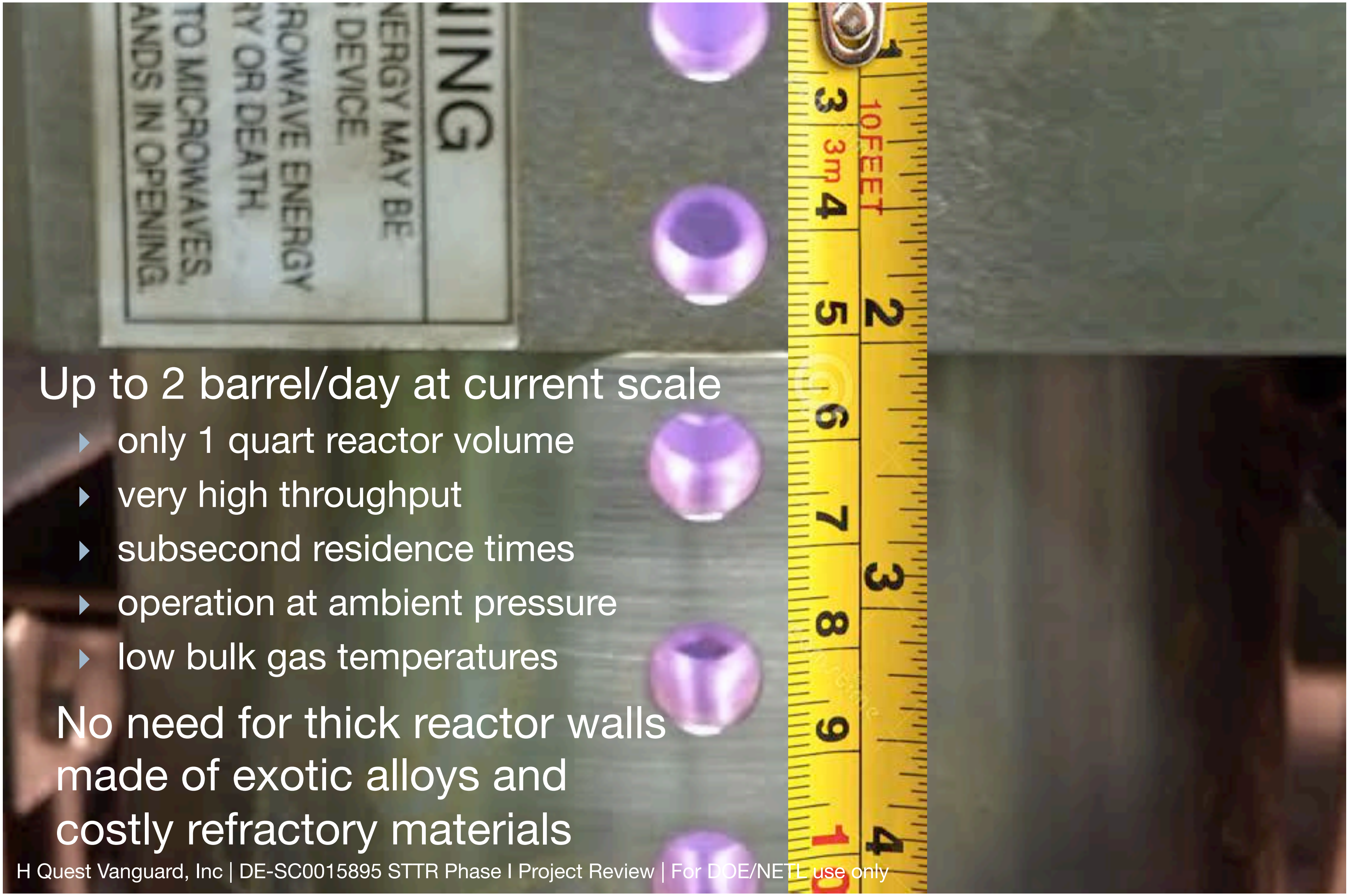
- Direct incorporation of methane carbon and hydrogen into products (methylation)
- Stabilization of radicals and suppression of secondary reactions
- Production of excess hydrogen satisfying all downstream upgrading needs.

Emergent process advantages:

- Improved oil quality compared to conventional pyrolysis / direct coal liquefaction
  - API > 10
  - % aromatic carbon < 50%
- In situ hydrogen production without SMR
- Virtually zero CO_2 emissions
- No process water consumption



Small-scale reactor results in low capital costs



Up to 2 barrel/day at current scale

- only 1 quart reactor volume
- very high throughput
- subsecond residence times
- operation at ambient pressure
- low bulk gas temperatures

No need for thick reactor walls made of exotic alloys and costly refractory materials

Envisioning a wide range of applications

Conversion of cost-advantaged domestic coal to:

- **crude oil and fuels**: unconventional oil at lower costs with improved environmental profile;
- **chemicals**: BTEX, alkylated and methylated aromatic basestocks, phenolics
- **materials**: activated carbon, specialty carbons, carbon fiber

Natural gas applications (TRL 2-4):

- **direct methane conversion / hydrogen production:** eliminates steam-methane reforming: reduces CO_2 emissions and water consumption
- **added-value chemicals**: ethylene, acetylene, etc
- **materials**: demonstrated production of specialty carbons
- **alternative GTL route**: incorporation of methane in coal and/or biomass fuels as an alternative approach to gas-to-liquids

Heavy oil upgrading opportunities (TRL 1-2):

- potential for **oil hydrotreating / hydrogenation** with little to no GHG emissions or water consumption
- potential for **asphaltene conversion**, oil **desulfurization**, **resid** and **heavy fuel oil** upgrading, other microwave-enhanced catalytic cracking applications

Synthetic crude: the largest market

Coal liquids have been refined to fuels since 1923[1]:

- to jet fuel[2,4], diesel[3] and gasoline[3]
- using conventional, oil refinery-employed processes
- stand-alone or blended with conventional petroleum
- at laboratory, pilot and industrial scales.

[1]Huff, *Coal Tar as a Source of Fuel for Internal-Combustion Engines*, Industrial & Engineering Chemistry, 1923
[2]Balster et al, *Development of an advanced, thermally stable, coal-based jet fuel,* Fuel Processing Technologies, 2008
[3]Kan et al, *Production of Gasoline and Diesel from Coal Tar via Its Catalytic Hydrogenation in Serial Fixed Beds*, Energy & Fuels, 2012
[4]Bartis & Flint, *Constraints on JP–900 Jet Fuel Production Concepts,* RAND Report, 2007

Wave Liquefaction™ syncrude

Wave Liquefaction™ coal-derived oils:

- have been **upgraded to fuels at laboratory scale** (initial DARPA study targeting jet fuels);
- will have **higher energy density and lower freeze point** than conventional distillate fuels;
- have projected **life-cycle greenhouse gas emissions** that are **10% lower** than for conventional petroleum fuels.

Coal fuels can be cleaner than petroleum!

HQuest

Compared to petroleum jet fuel production, per barrel:

- Life-cycle emissions can be **10% lower**
- Direct CO_2 process emissions can be **60% lower**

Jet Fuel Production: CO_2 emission comparison

	Current State of the Art Technologies[1]			
	Conventional Petroleum	Indirect Coal Liquefaction (FT)	Direct Coal Liquefaction (CMSL)	*Wave Liquefaction*™[2] (Grid Power)
CO_2 Process Emissions (kg_{CO2}/bbl)	**33**	706	434	**13**
Well-to-Wheels CO_2 (gCO2eq/MJ)	**88**	195	157	**80**

Key Factor: Hydrogen plant elimination

[1]Life Cycle Greenhouse Gas Emissions from Alternative Jet Fuels, MIT 2010
[2]DARPA HR0011-10-0088-FTR1107 Final Technical Report, Battelle/PNNL 2013

Compared to other unconventional oil plays

	Tight (shale) oil	Deep water	Extra heavy oil Tar sands	Conventional coal-to-liquids	Wave Liquefaction™
Marginal costs to produce 1 barrel	\$50-\$77[1]	\$54-\$60[1]	\$35-\$75[2]	>\$66[2]	\$30-\$45[3]
Capital intensive	YES	YES	YES	YES	**NO**
Technology intensive	YES	YES	YES	YES	**NO**
Energy intensive			YES	YES	**NO**
Environmental impact	High water use, contamination, high GHG emissions	Risk of catastrophic spills (Deepwater Horizon!)	High CO_2 emissions, high water consumption	High CO_2 emissions, high water consumption	No CO_2 emissions
Other challenges	Fast well depletion (90% in 3 years), high transport costs			Economic only at large scales	No Depletion! Economic even at smaller scales

[1]http://uk.reuters.com/article/2014/08/15/opec-budget-idUKL6N0QL1VY20140815,
[2]http://www.reuters.com/article/2009/07/28/oil-cost-factbox-idUSLS12407420090728
[3]Battelle techno-economic analysis, 2012. The Battelle techno-economic analysis "all-in" cost includes coal, gas, power, salaries, maintenance, insurance, G&A, interest, taxes, and depreciation for operations in a commercial-scale plant.

Impact on Appalachia (example)

A single 10,000 barrel/day plant:

- Projected to cost only $150M.
- Profitable even at low oil prices
- **Creates 80 direct jobs**
- Induces > **300 indirect jobs**
- Needs zero government subsidies

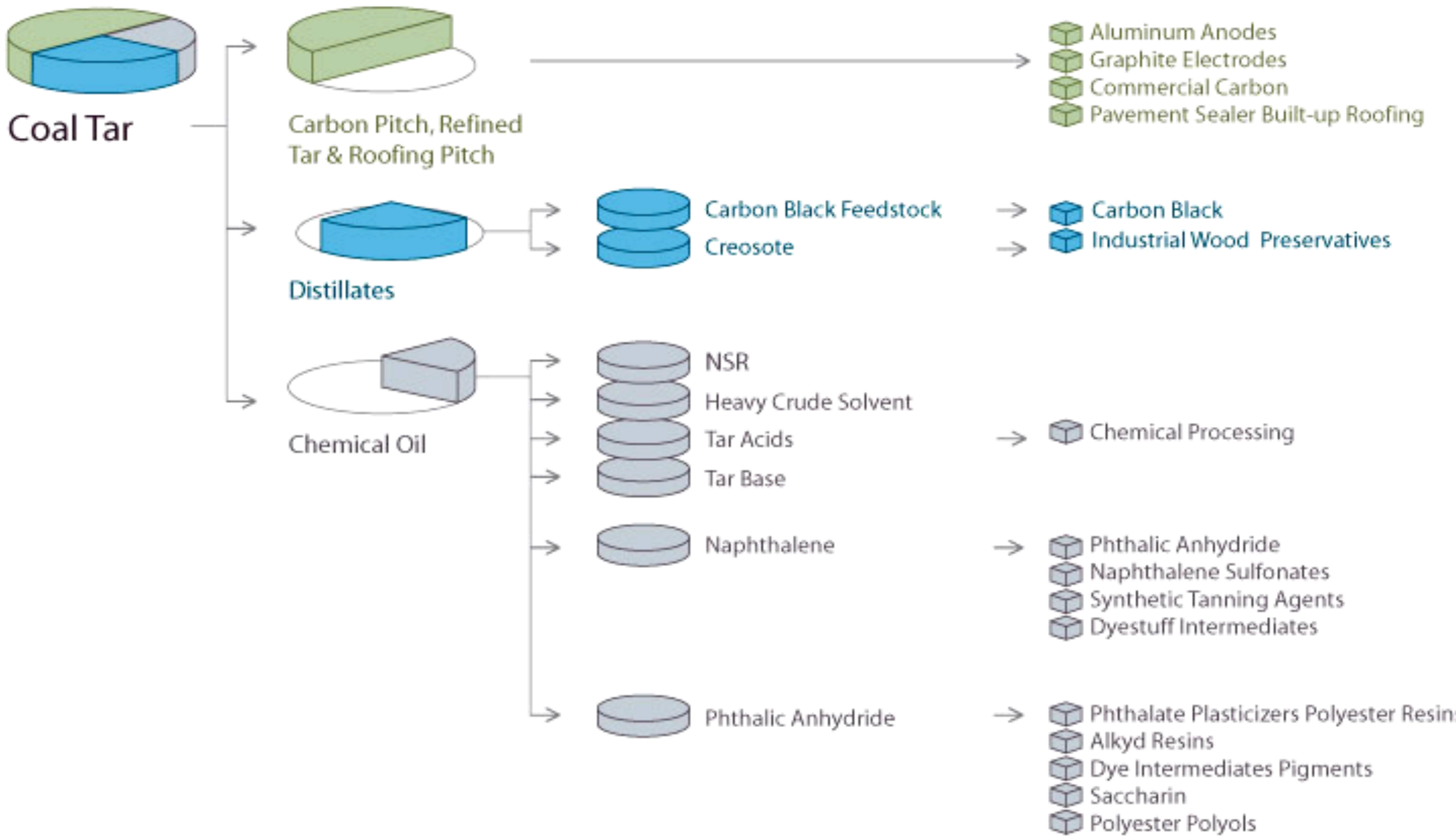
Impact of just one refinery:

- Catlettsburg refinery processes 242,000 barrels/day (bpd)
- 25 mine-mouth 10,000 bpd plants distributed in KY, WV, PA and OH would be required to supply this refinery
- Brand new demand for 30M tons of coal / year and > **8000 new direct and indirect jobs**

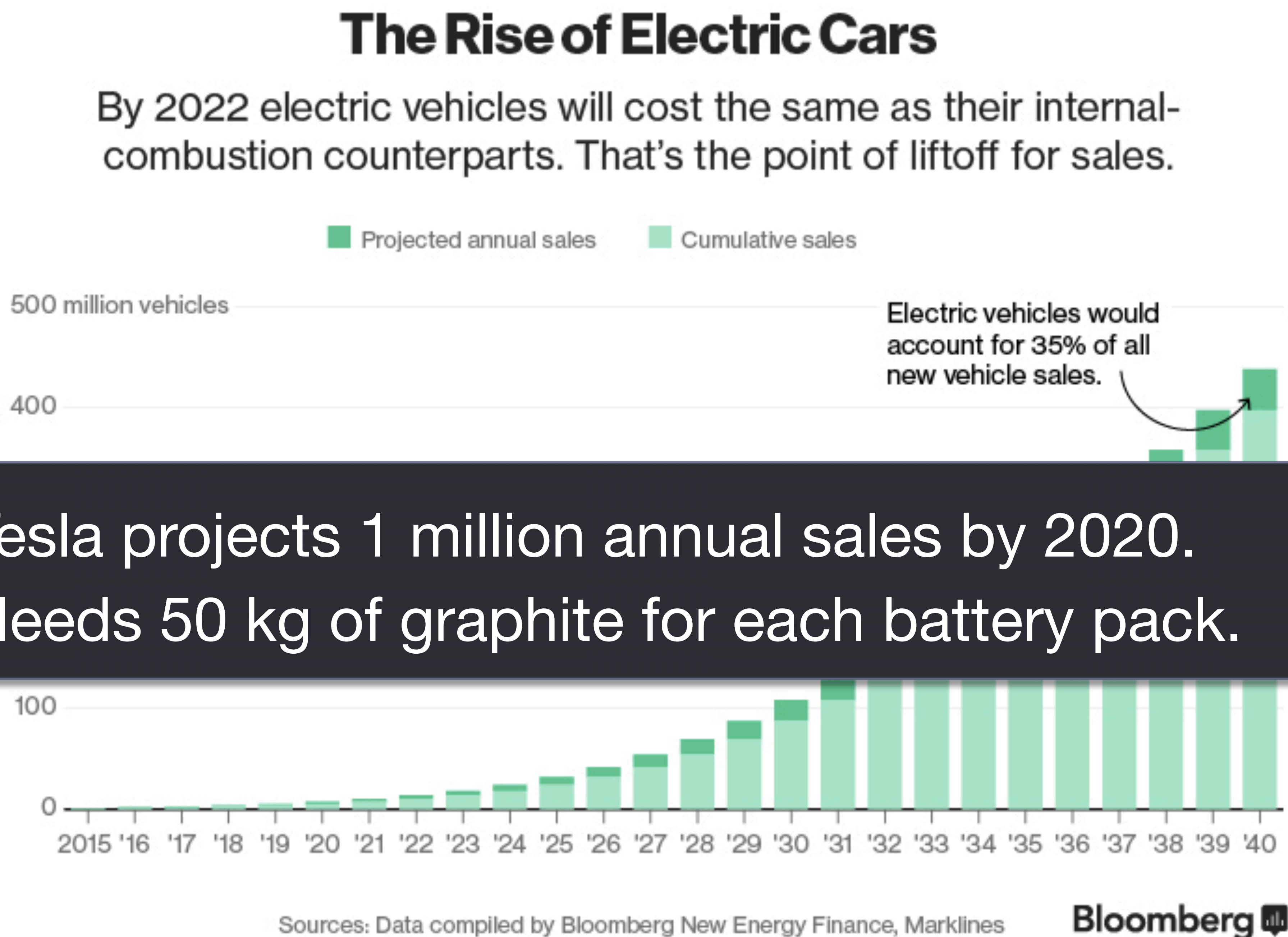
Supplying a single 242,000 barrel/day refinery would:

- require ~30M tons of coal per year (~30% of 2015 WV coal production)
- create upwards of 8000 direct mining and manufacturing jobs

Conventional uses for coal liquids



Source: Koppers, Inc.



Tesla projects 1 million annual sales by 2020.
Needs 50 kg of graphite for each battery pack.

http://www.bloomberg.com/news/articles/2016-05-04/tesla-s-wild-new-forecast-changes-the-trajectory-of-an-entire-industry
http://www.reuters.com/article/us-tesla-results-idUSKCN0XV2JL

High-grade synthetic graphite

Demanding applications

- Nuclear industry, chemical processing, aerospace, energy generation, and others

Preferred electrode material for lithium-ion batteries

- Tesla alone would require >50K tons/year by 2020.
- Corresponds to demand of 0.5M-1M tons of coal per year, *(based on 5-10% yields per ton of coal)*

Carbon fiber: material of the 21st century

Set to discplace metals in manufacturing and construction

- Lighter and stronger than steel
- More conductive than aluminum or copper
- Withstands extreme temperatures, does not corrode, does not expand when heated, …

Low-cost coal-derived precursor can catalyze explosive growth of the carbon fiber market

Use restricted to aerospace, sports equipment, luxury vehicles

- High cost is the hurdle to broad industrial adoption: >$20 / kg
- Cost of petroleum-derived precursors: $5.00 / kg
- **Cost of a coal-based precursor could be as low as $0.40 / kg**

Coal-derived carbon fiber

Of the world's 15 carbon fiber producers, only two (Mitsubishi and Nippon Steel) produce the highest grade graphitic carbon fibers from coal tar pitch.

Coal tar pitch is a heavy by-product of metallurgical coking plants with inconsistent properties. It requires extensive processing and cleaning for use as carbon fiber precursor.

Today, the highest grade carbon fiber (>$80/kg) is made from coal tar pitch. High precursor production costs prevent wide adoption of coal-based carbon fiber.

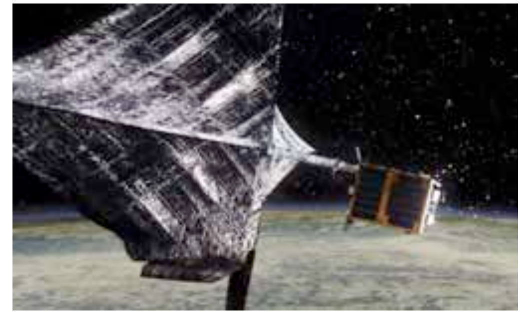
Wave Liquefaction™ can convert coal directly into pitch with desired properties avoiding contamination, which drastically reduces costs of conversion and carbon fiber production.

Wave Liquefaction™ can dramatically decrease production costs and promote broad adoption of coal-derived carbon fiber in industrial sectors from infrastructure to energy to manufacturing.

Markets for coal-based carbon fiber

Aerospace and national defense

- Engine components for jet aircraft, helicopters, and rockets
- Structural elements for spacecraft and satellites
- Heat pipes and shields for spacecraft and return vehicles



Civil engineering and public infrastructure

- Structural and seismic reinforcement
- Corrosion-resistant components and tubing
- Concrete bridge and structure repairs

Environment and energy

- Flywheels, centrifuges and rotors
- Wind turbine blades
- Tubing for drilling rigs and pipelines

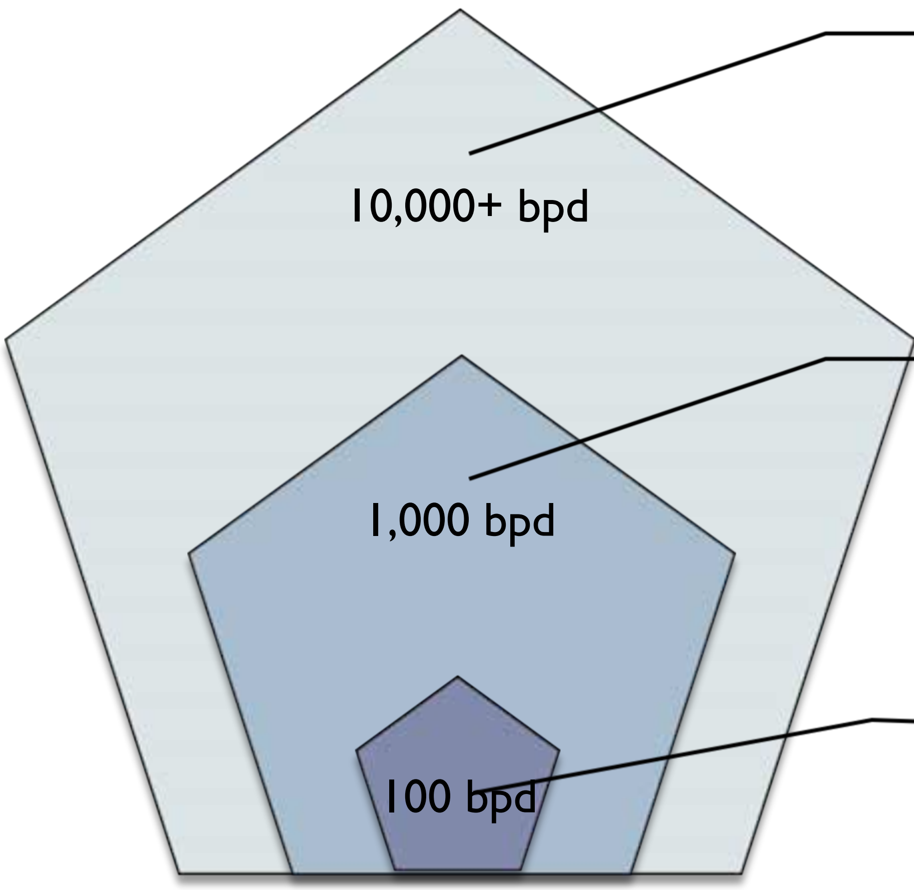
Automotive and manufacturing

- Lighter drivetrains, brakes, and injection-molded parts
- Rollers and other rotating machinery components
- Heat conductors and insulators
- Precision robotic manipulators

Commercialization strategy: staged deployment

Quest

Target early revenue generation at small scales. Incrementally build capabilities and enter larger markets.



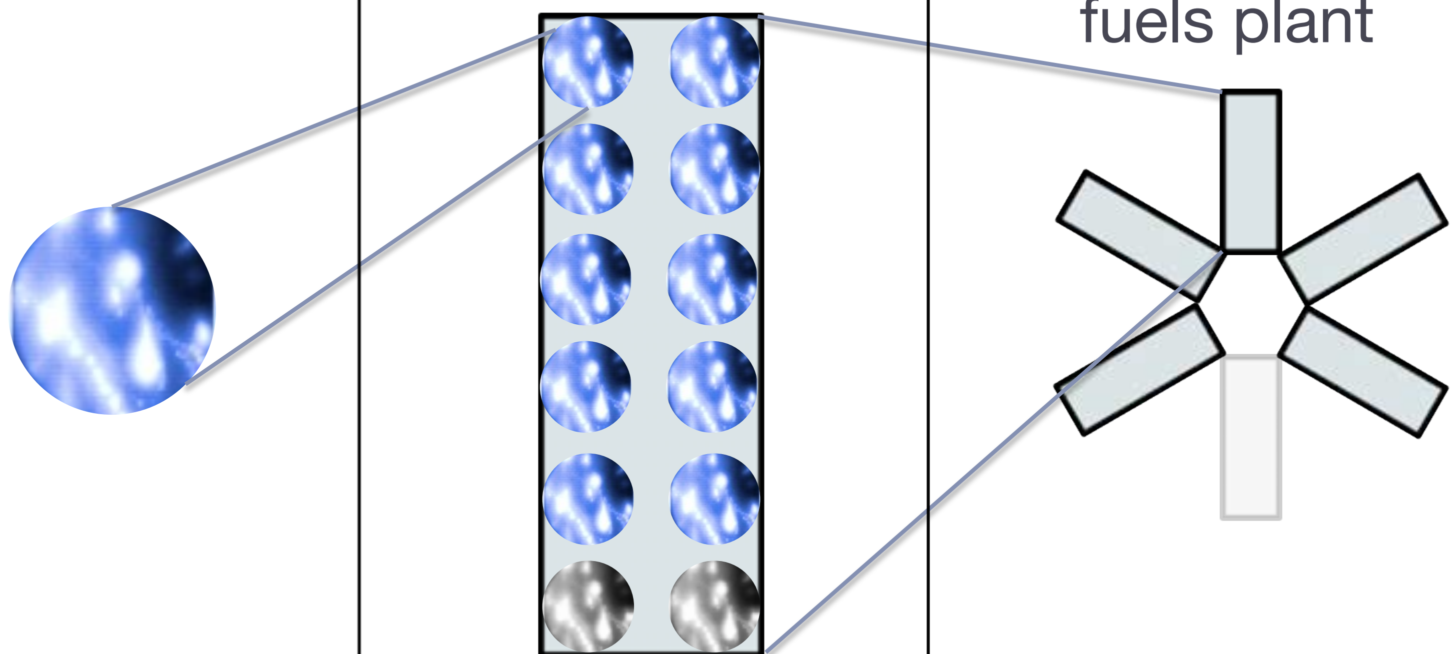
Scale:	10,000+ barrel/day
System:	fully proven technology
Goals:	commercial exploitation
Product:	synthetic crude oil

Scale:	1,000 barrel/day
System:	first commercial plant
Goals:	proving scalability
Product:	coal chemicals

Scale:	100-200 barrel/day
System:	industrial demo
Goals:	derisking & profitability
Product:	materials, chemicals

Incremental, modular scale-up

Year 3	Year 4-6	Year 6-8
Single industrial scale reactor	First commercial plant (single-train)	Commercial synthetic oil & fuels plant



Year 3		Year 4-6		Year 6-8	
Scale:	100-200 barrel/day	**Scale**:	1,000 barrel/day	**Scale**:	At least 10K barrel/day
System:	industrial demo	**System**:	first commercial plant	**System**:	fully proven technology
Goals:	demonstration, early revenue	**Goals**:	profitability	**Goals**:	commercial exploitation

Technology development timeline

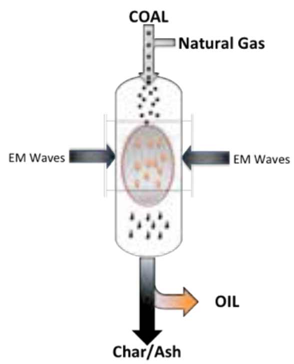
Development of an alternative approach to direct liquefaction, specifically addressing the economic and environmental challenges associated with conventional liquefaction

- 2009-2011: DARPA funding[1] to build a prototype reactor at a DOE National Laboratory
- 2011-2013: H Quest funding to build laboratory-scale system and to test 9 different coals
- 2014: H Quest Vanguard, Inc started commercialization in Pittsburgh: 5,000 sq ft high bay facility at the former Gulf Labs research campus (currently U-PARC)

[1]Contract no. HR0011-10-0088

Scale-up progression

2009-2010



Scale: N/A
System: concept

2010-2011

Scale: 30 g/hr
System: bench

2012-2013

Scale: 150-900 g/hr
System: laboratory

2014-2016

Scale: 3 kg/hr
System: engineering

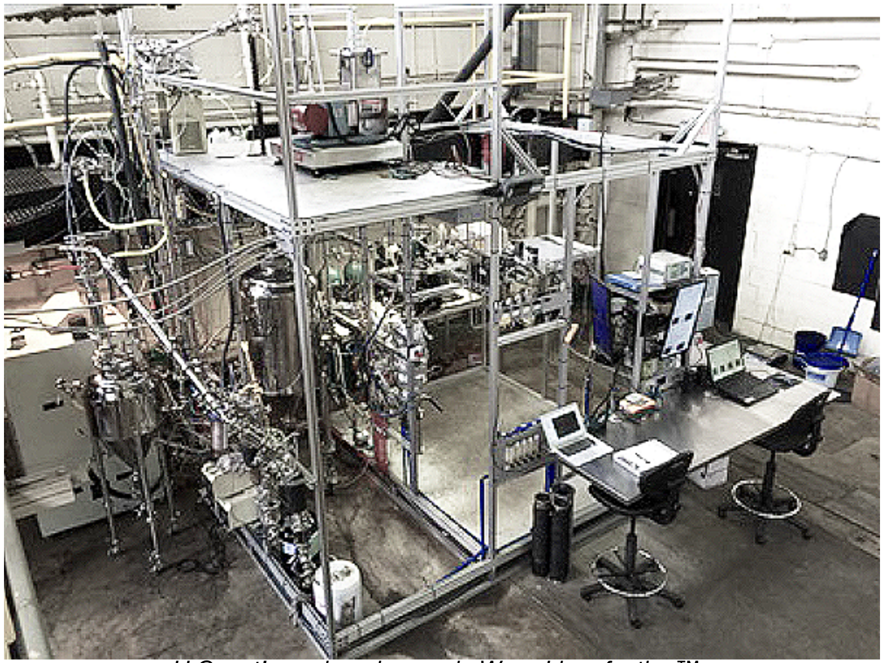
NOW

2017-2018

Scale: 30 kg/hr
System: pilot

- Since 2010, the process has been scaled-up 100x times.
- Starting in 2014, technology development takes place at H Quest Vanguard, Inc. facility in Pittsburgh, PA.
- Last step to commercialization: 30 kg/hr pilot system.

Present status and development plan



H Quest's engineering-scale Wave Liquefaction™ pilot system in the high bay of the U-PARC facility

Engineering system

- Small reactor (2.45GHz)
- Supports technology research and development
- Allows quick evaluation of technical solutions
- Limited by balance of plant
  - 5 kg coal hopper
  - limited recovery system
- Not yet production ready

Only one step needed to scale-up from the current (laboratory) to industrial reactor size (~ 100 barrel/day).

Upgrading the engineering system to 30 kg/hr (pilot) will diminish the technical risk of scaling up to demo plant.

WAVE LIQUEFACTION™ PROCESS DEVELOPMENT AND DEMONSTRATION FOR THE CLEAN AND EFFICIENT MANUFACTURING OF CHEMICALS

Clean and efficient coal conversion technology opening new utilization pathways for domestic coal resources

Technology Summary

- Wave Liquefaction™ is a novel coal conversion technology applicable to a wide range of domestic coals, targeting production of ***fuels, chemicals, and carbon materials***. It achieves rapid (< 1 second residence times)***, high-throughput conversion at ambient pressure*** and relatively low bulk temperatures by creating localized reaction zones using ***focused microwave energy***.
- Originally, the Wave Liquefaction™ technology was developed at a DOE National Lab with DARPA funding, targeting production of jet fuel from domestic coal resources with environmental and financial profile ***competitive with conventional petroleum processes***. Break-even costs for coal-derived synthetic crude oil lie in the $30-$45/barrel range depending on the coal and site specifics.
- Conversion reactors are small, ***modular*** and are electrically driven. Unlike conversion processes of the past, Wave Liquefaction™ ***has no CO_2 emissions*** or water consumption, enabling deployment ***of clean, efficient, small-scale*** processing plants directly at the mine sites.

Project Activities and Deliverables

- Deploy a Wave Liquefaction™ pilot system (30 kg/hr of coal / 2 barrel/day liquid production with 330 kWh/barrel energy inputs)
- Collect engineering data and execute endurance tests of the pilot system (up to 120 hours of continuous operation)
- Perform feasibility testing of an industrial-scale prototype reactor
- Prepare a commercialization package comprised of pre-FEED of the next deployment scale (100 bpd demonstration) plant, techno-economic analysis for 1,000-10,000 bpd deployments, and a detailed commercialization plan, including market studies.

Project Objectives

- Advance Wave Liquefaction™ TRL from 4 to 6
- Reduce commercial and eliminate key technical risks
- Advance the process to the point of commercial deployment

Project Summary

Principal Investigator: Dr. James Strohm
Prime: H Quest Vanguard, Inc.
Key project team members:

- thyssenkrupp Industrial Services
- Penn State University
- Gerling-Muegge /
- Gerling Applied Engineering, Inc.
- Sulzer ChemTech

Total project cost: $4.5M
Team's cost share: $2.0M

R&D team members

Quest

thyssenkrupp

ThyssenKrupp-Uhde is one of the world's leading engineering companies, has over 130 years experience in all aspects of coal handling and processing, and holds a sizeable portfolio of coal-to-liquids technologies.

MUEGGE GERLING

Gerling Applied Engineering (GAE) is a wholly-owned subsidiary of Muegge GmbH – the world leader in development, design, and fabrication of high-power microwave components.
John Gerling is a technical advisor to H Quest Vanguard.

SULZER

Sulzer is a leading supplier to chemical, refining, and related industries and has extensive experience and IP portfolio in mist/aerosol elimination and distillation/absorption columns

PennState College of Earth and Mineral Sciences

Dr. Randy Vander Wal has extensive expertise in plasma diagnostics and characterizations of carbon materials and hydrocarbon liquids. His group closely collaborates with H Quest on a number of proposals and projects.

Wave Liquefaction™ summary

Conversion of U.S. coal into crude oil, fuels, and advanced materials:

- Creates hundreds of thousands of new coal, energy, and manufacturing jobs
- Ensures America's energy independence and national security
- Unlocks the true, vast value of the 256 billion tons of U.S. coal reserves

Wave Liquefaction™ is a game changing technology:

- Opens vast markets to American coal and is profitable at low oil prices
- Has virtually zero CO_2 emissions or water consumption
- Has lower capital costs and shorter deployment costs than alternatives
- Requires no subsidies or government mandates at commercial scale