

A Brief Overview of Coal to Chemicals Opportunities and Obstacles



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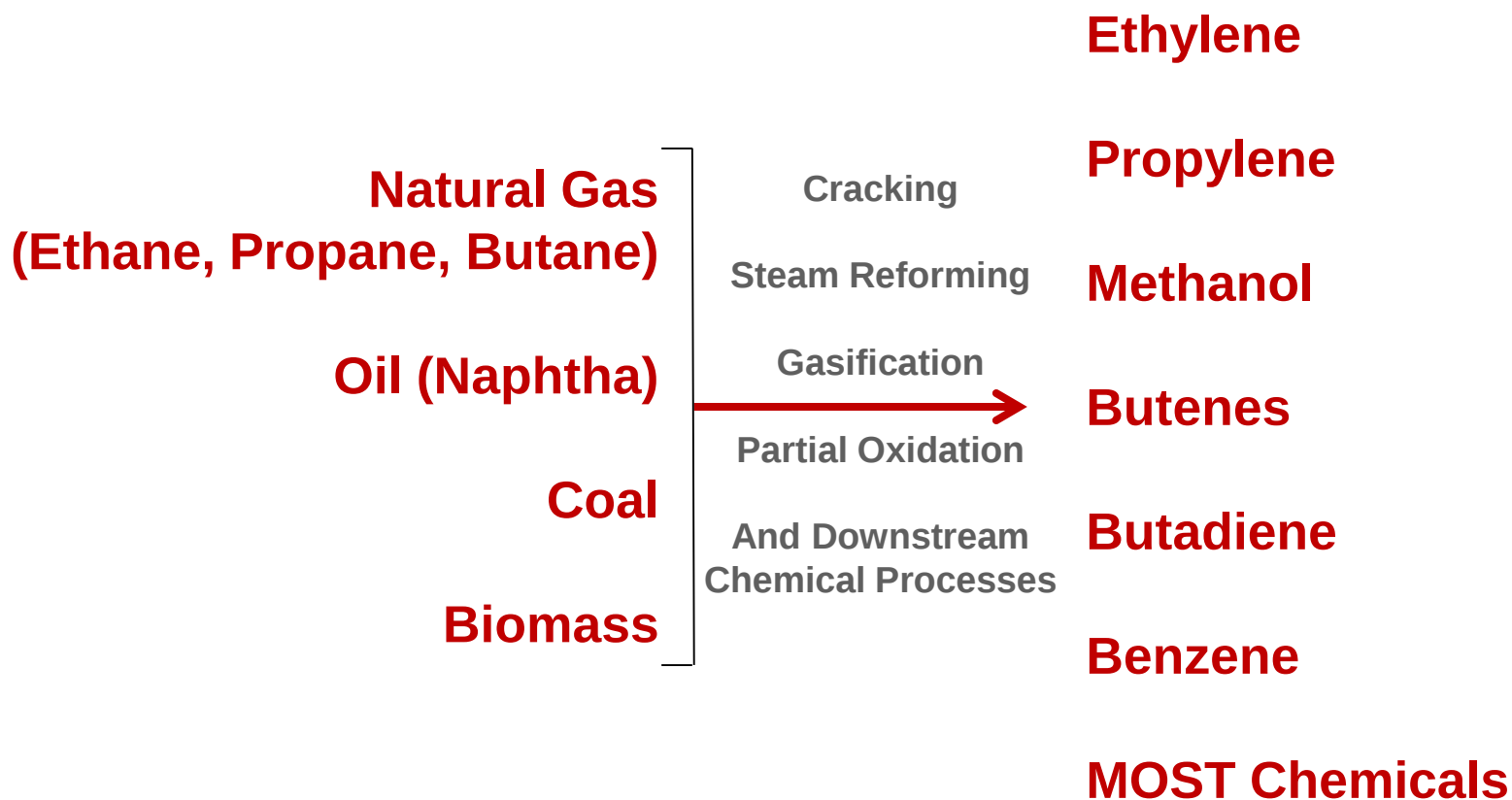
**Sasol Coal-to-Liquids Plant
Secunda South Africa**

OUTLINE

- ✓ **The Good**
- ✓ **The Bad**
- ✓ **The Balance**
- ✓ **The Bottom Line**

The Good

Coal Another Hydrocarbon ... and Chemical Feedstock



The Good

Basic Coal Conversion Chemistry

◆ Indirect Coal Liquefaction

1. Gasification



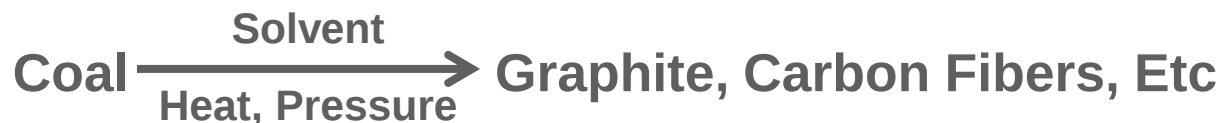
2. Syngas to Chemicals ... Fischer-Tropsch (FT) Shown



◆ Direct Coal Liquefaction



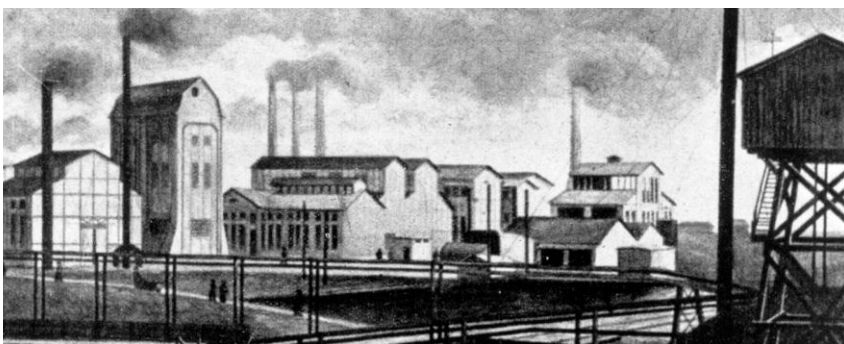
◆ Solvent Extraction and Other



The Good

COAL TO CHEMICALS FAR FROM NEW

- Direct hydrogenation of coal discovered in 1869
- Technology advanced in the early-to-mid-1900s
- Farben commercialized in Germany in 1930s & 1940s



Bergius Factory, Germany, Circa 1930s

Franz Fischer at Work in 1918

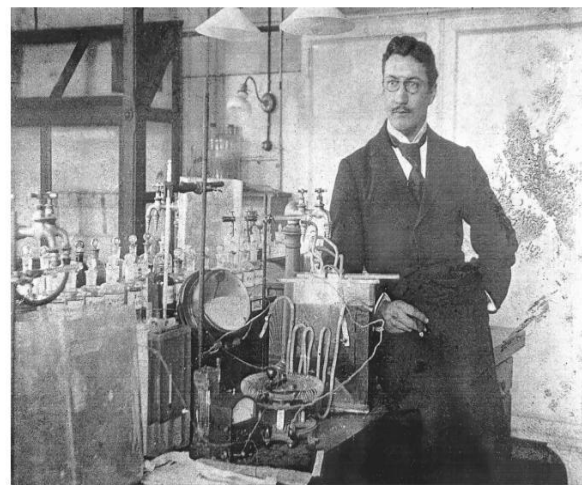


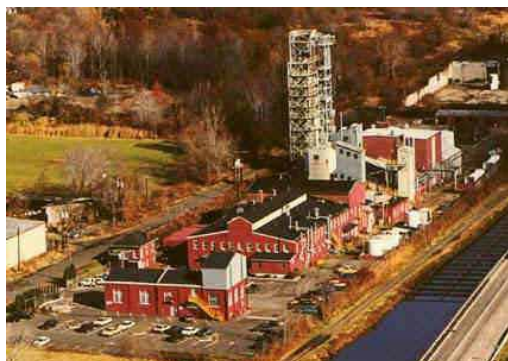
Photo: M. J. 200

- Indirect coal conversion of syngas discovered by Fischer and Tropsch in 1920s
- Ruhrchemie commercialized FT in Germany in 1936

The Good

Coal-to-Chemicals Plants

- **Reportedly about 40 large-scale, coal-to-chemicals plants in operation worldwide ... 35 in China**
- **Another 79 or so plants under construction or planned**
- **LOTS of demonstration plants of various sizes**



Lawrenceville, NJ



Inner Mongolia, China



Catlettsburg, KY

The Good

Coal-to-Chemicals Plants ... A FEW NOTABLE EXAMPLES



- Sasol I, II, III South Africa
- ExxonMobil MTG New Zealand
- Eastman Chemical Coal Gasification Kingsport

**SASOL II and III ...
Secunda South Africa**

THE GOOD

- ✓ Coal is another source of carbon and hydrogen ... like oil and natural gas
- ✓ Coal-to-Chemicals technology exists and proven
- ✓ Long history of demonstration and commercial facilities



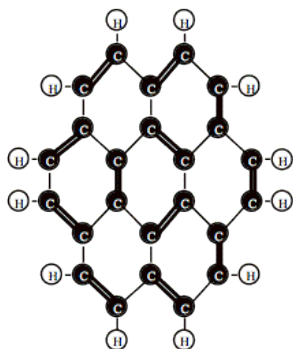
**UNFORTUNATELY ...
IT'S NOT ALL GOOD**



The Bad

Coal NOT JUST Another Hydrocarbon

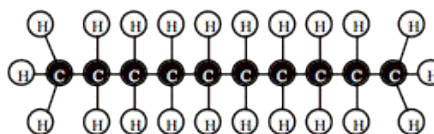
COAL



**COMPLEX SOLID WITH
ASH, EXTRAS**

H:C 0.5:1

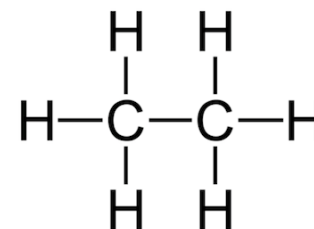
OIL (Naphtha)



**LESS COMPLEX,
FAIRLY CLEAN LIQUID**

H:C 2:1

GAS (Ethane)



**SIMPLE GAS AND
FAIRLY PURE**

H:C 3:1

The Bad

Need to Convert Coal to Liquid or Gas and Add H₂

◆ Indirect Coal Liquefaction

1. Gasification



2. Syngas to Chemicals ... Fischer-Tropsch (FT) Shown



◆ Direct Coal Liquefaction



The Bad

ECONOMICS ... AND RISK-REWARD ... 101

- **LARGE CAPITAL INVESTMENT ... \$1B to \$4B+**
- **FIERCE COMPETITION ... Oil and natural gas processes are mature and widespread**
- **TECHNICAL UNCERTAINTY ... Especially compared to competition**
- **ENVIRONMENTAL CONCERNS ... More NO_x, SO_x, VOCs, solid residues ... and CO₂**

The Bad

ECONOMICS ... AND RISK-REWARD ... 101



VS



VS



**ALMOST ALL HOUSEHOLD
AND CONSUMER PRODUCTS**

THE BAD

- ✓ Coal NOT JUST another source of carbon and hydrogen
... More complex, lower H:C, harder to process
- ✓ Higher technical and economical risk
compared to natural gas and oil
- ✓ Long commercial history pales in
comparison to petrochemical industry

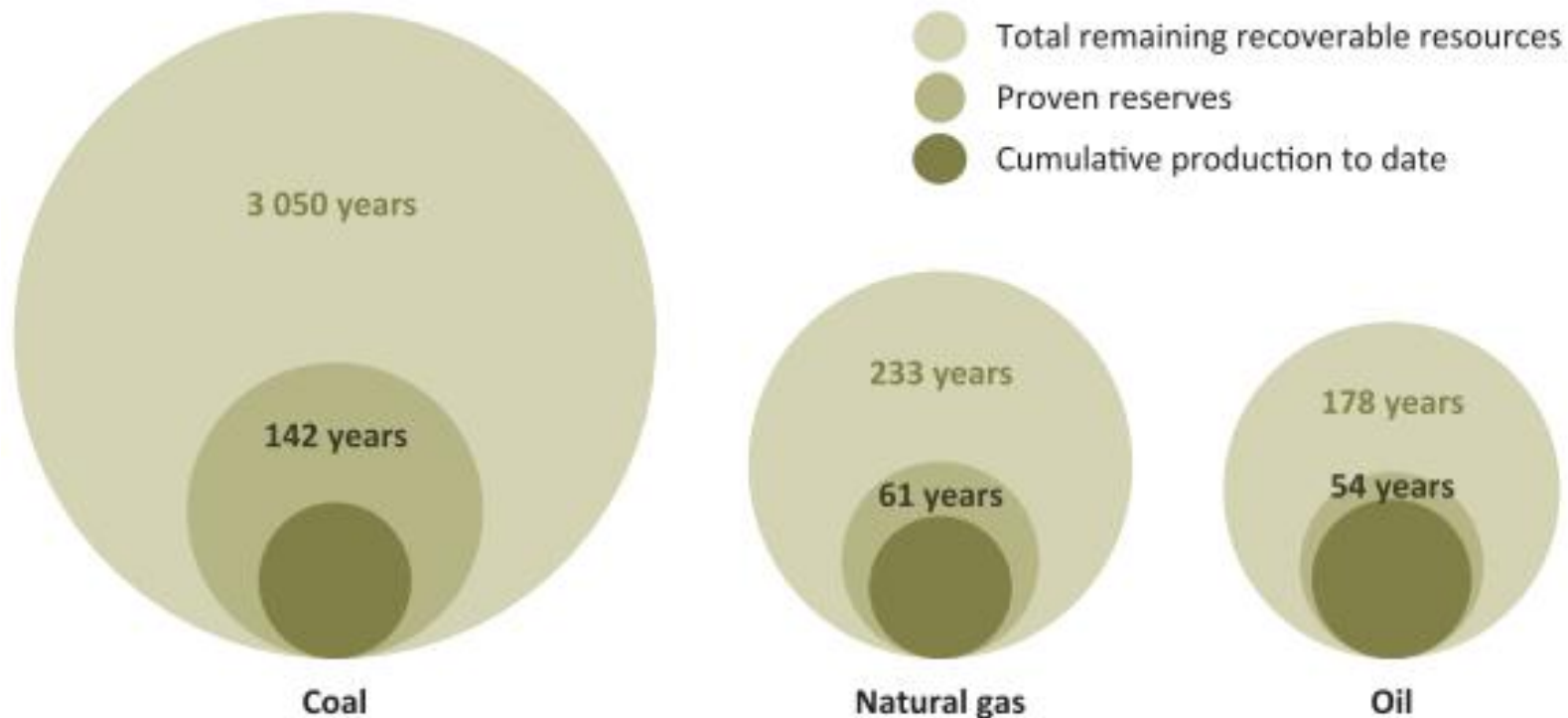


THEN AGAIN ... THERE'S A BALANCE



The Balance

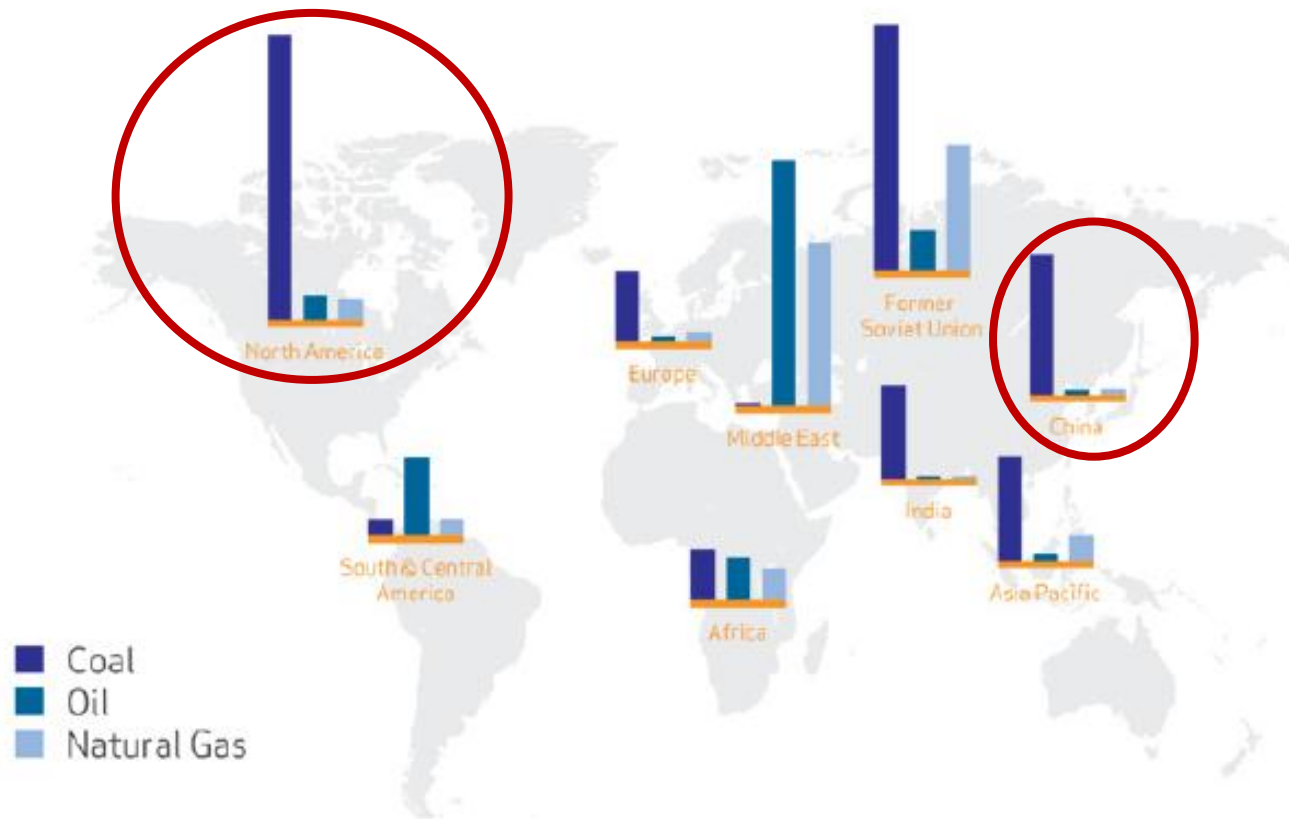
COAL RESERVES FAR EXCEED GAS AND OIL



Circa 2012 Data ... May not adequately account for new shale reserves

COAL RESERVES FAR EXCEED GAS AND OIL ... ESPECIALLY IN SOME AREAS

Location of the world's main fossil fuel reserves (billion tonnes of oil equivalent)



Source: BP Statistical Review of World Energy 2011

The Balance

AND SO ... WELL ... CHINA



Shenhua Plant
100,000 BPD

- Large and growing demand for everyday products ... chemicals and plastics
- Large coal reserves ... low gas and oil
- Cheap and stranded coal ... \$25 per ton and lower in some of China's inland provinces

The Balance

SIMILAR ... BUT NOT THE SAME ... IN UNITED STATES

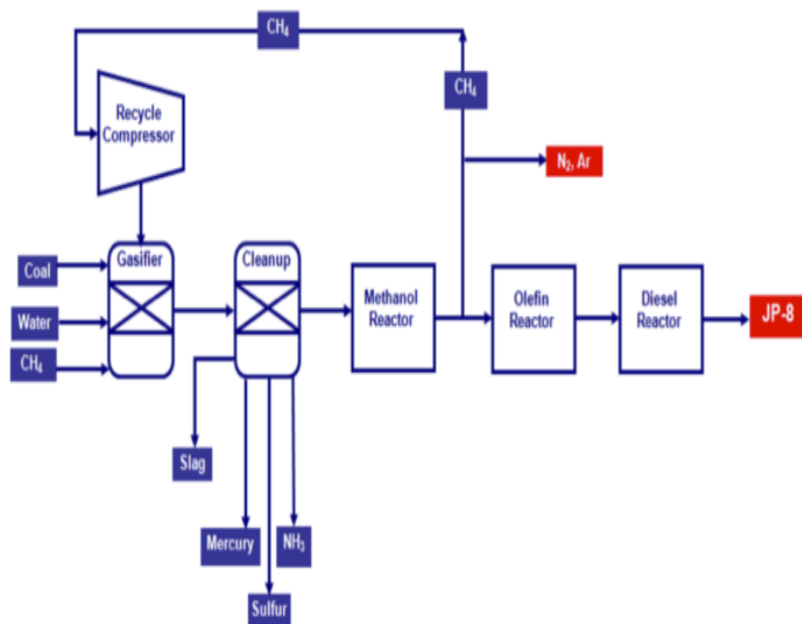


- Large demand for products ... but not growing as rapidly
- Large coal reserves ... but also ample gas and oil
- Stranded ... if not as cheap ... coal in some states

The Balance

**INNOVATION MAY PLAY A ROLE AS WELL ...
COULD EVEN BE DISRUPTIVE**

SRI International Coal-to-Liquids Process



- No water consumption or carbon dioxide emissions
- 50+% reduction in capital
- Natural gas supplies H₂ to convert coal to syngas

The Balance

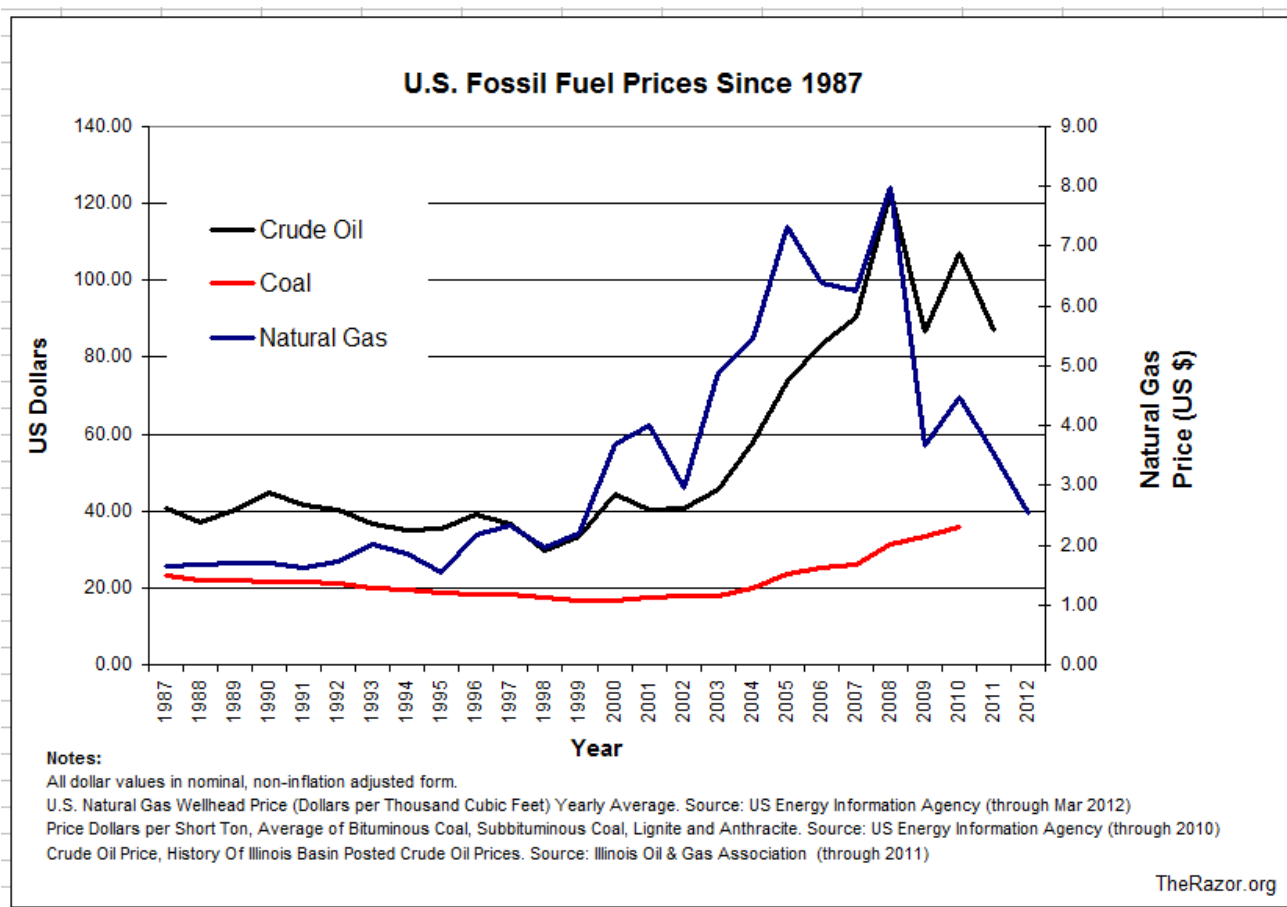
**INNOVATION MAY PLAY A ROLE AS WELL ...
COULD EVEN BE DISRUPTIVE**

POSSIBLE “HOLY GRAIL” ... TURN CO₂ INTO PRODUCTS

- Covestro building facility in Germany to use CO₂ to produce high-quality plastics
- Lots of research to use CO₂ to make liquid fuels, alcohols, and other chemicals and materials
- However ... CO₂ chemistry is TOUGH ... CO₂ is a very stable, unreactive molecule

The Balance

COAL PRICES TEND TO BE LOWER AND LESS VOLATILE



THE BALANCE

- ✓ Coal reserves far exceed gas and oil ... especially in some areas ... and can be “cheap”
- ✓ Innovation may play disruptive role in coal-to-chemicals
- ✓ Coal price tends to be lower and less volatile than gas and oil



The Bottom Line



- ROI must be (MUCH?) higher for coal-based chemicals to induce large investments
- Coal-based chemicals profitable when oil above \$50/bbl
- Coal-based chemicals lose money when oil below \$35/bbl
- Coal-based chemicals may be a viable option to monetize abundant, stranded, cheap coal reserves
- Coal-to-chemicals tough ... even for China ... but worth continuing development and some commercial investment

BIG THANKS

- ✓ **Richard Bajura**, Director, National Research Center for Coal and Energy (NRCCE), West Virginia University
- ✓ **Qingyun Sun**, Associate Director, US-China Center at West Virginia University
- ✓ **Andrew Maloney**, PhD Student, MIT ... Chief Engineer, WVU ChE, Class of 2016
- ✓ **Burt Davis**, Associate Director, Clean Fuels & Chemicals, University of Kentucky Center for Applied Energy Research