Coal Conversion – Pathway to Alternate Fuels

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Overview

- DOE and Coal Liquefaction RD&D
- Coal – A Significant Source of Energy
- Coal Liquefaction Technology and Status
- Current and Growing Interest in Liquefaction

Components of Earlier DOE RD&D Coal Liquefaction Program

- Technology Screening – Bench and pilot plant projects (1964–1976)
- Component I (1976–1982)
  - Large-scale demos of Phase I processes
  - Thermal and catalytic hydrogenation processes
- Component II (1976–1999)
  - Research program
  - Pursue improvements and alternatives based on better scientific understanding
- Component III (1980–1998)
  - Bench-scale development of Phase II processes
  - Overcome techno-economic limitations of Phase I processes
  - Catalytic hydrogenation processes

Coal Conversion Processes

- Carbonization and Pyrolysis
  - Low severity (mild gasification)
  - High temperature
- Direct Liquefaction
  - One-stage reactor technology
  - Two-stage reactor technology
  - Co-processing
  - Hybrid
- Indirect Liquefaction
  - Gas reactors
  - Slurry reactors

Coal Liquefaction Technologies

Mild Pyrolysis	Single-Stage Direct Liquefaction	Two-Stage Direct Liquefaction	Co-Processing and Dry Hydrogenation	Indirect Liquefaction
• Liquids from Coal (LFC) Process – Encoal • Coal Technology Corporation • Univ. of North Dakota Energy and Environmental Center (EERC)/AMAX R&D Process • Institute of Gas Technology • Char, Oil Energy Development (COED)	• Solvent Refined Coal Processes (SRC-I and SRC-II) – Gulf Oil • Exxon Donor Solvent (EDS) Process • H-Coal Process – HRI • Imhausen High-Pressure Process • Conoco Zinc Chloride Process • Kohleoel Process – Ruhrkohle • NEDO Process	• Consol Synthetic Fuel (CSF) Process • Lummus ITSL Process • Chevron Coal Liquefaction Process (CCLP) • Kerr-McGee ITSL Work • Mitsubishi Solvolysis Process • Pyrosol Process – Saarbergwerke • Catalytic Two-Stage Liquefaction Process – DOE and HRI • Liquid Solvent Extraction (LSE) Process – British Coal • Brown Coal Liquefaction (BCL) Process – NEDO • Amoco CC-TSL Process • Supercritical Gas Extraction (SGE) Process – British Coal	• MITI Mark I and Mark II Co-Processing • Cherry P Process – Osaka Gas Co. • Solvolysis Co-Processing – Mitsubishi • Mobil Co-Processing • Pyrosol Co-Processing – Saabergwerke • Chevron Co-Processing • Lummus Crest Co-Processing • Alberta Research Council Co-Processing • CANMET Co-Processing • Rheinbraun Co-Processing • TUC Co-Processing • UOP Slurry-Catalysed Co-Processing • HTI Co-Processing	• Sasol • Rentech • Syntroleum • Mobil Methanol-to-Gasoline (MTG) Process • Mobil Methanol-to-Olefins (MTO) Process • Shell Middle Distillate Synthesis (SMOS)

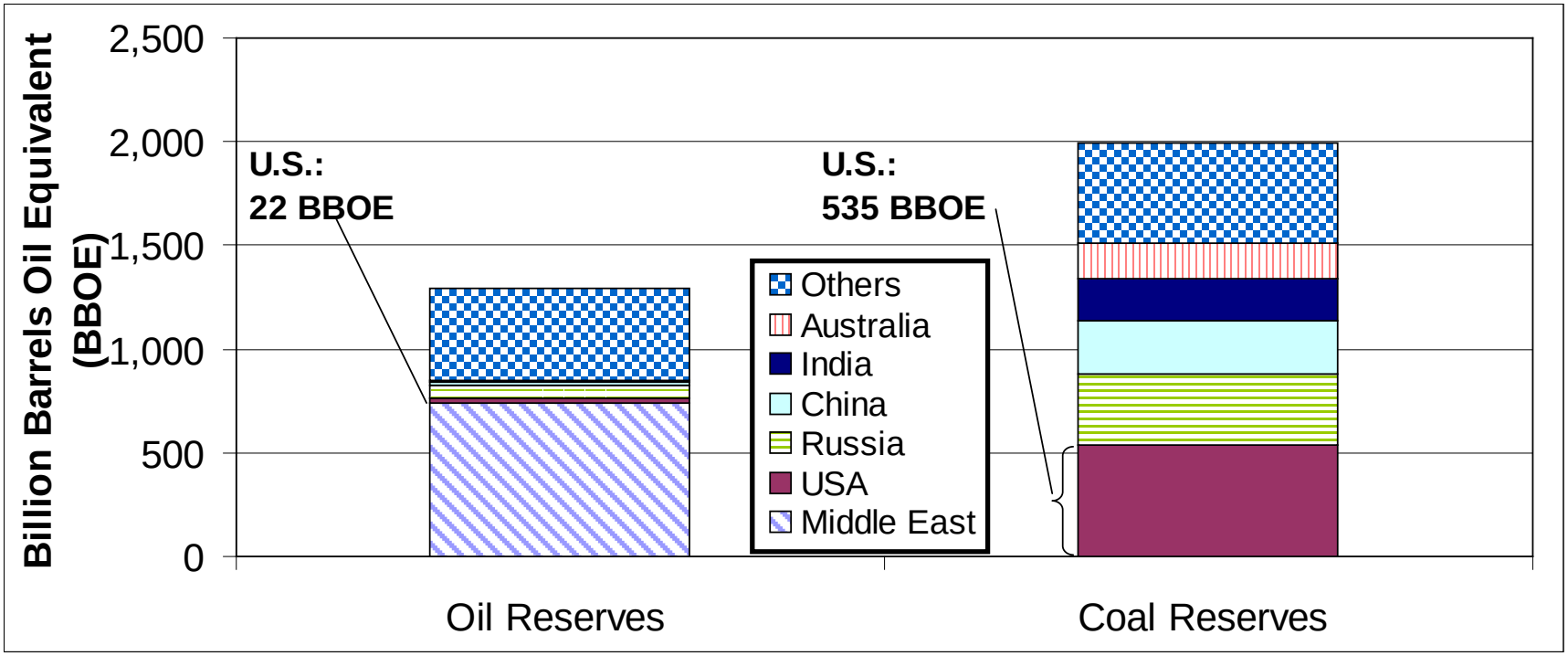
Source: "Coal Conversion – A Rising Star," 23rd Int'l Pittsburgh Coal Conference, September 25-28, 2006.

Why Coal-To-Liquids (CTL)?

- Energy Security
  - Size of coal resources
  - Distribution of resources
- Environment
  - Utilization of clean coal technology
  - Sequestration technology expected
- Flexibility
  - Advanced technology
  - Co-production capability
- Economics
  - Competitive with alternatives
  - World oil price volatility

Global Supplies

Comparison of World Oil and Coal Reserves

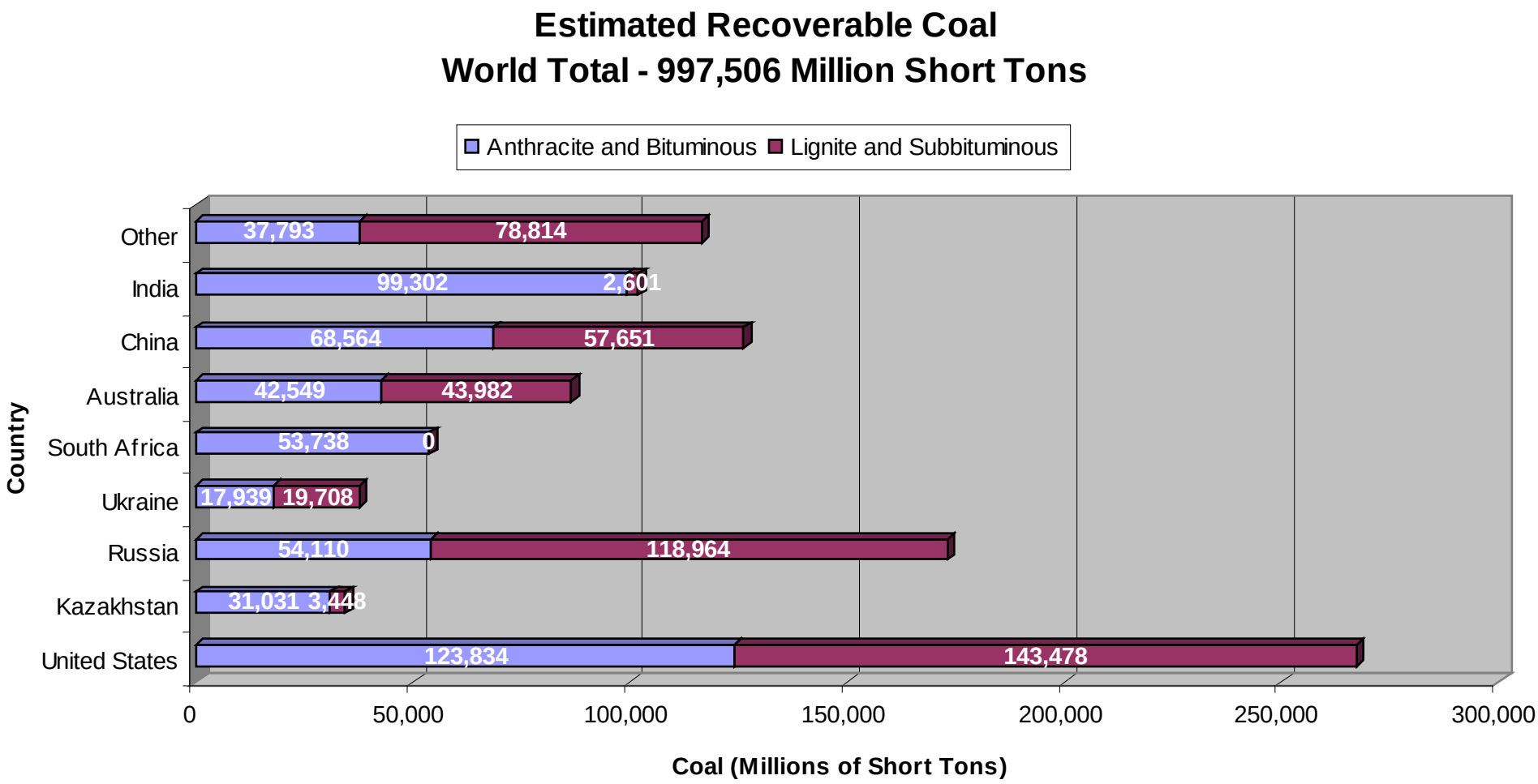


- World oil demand will grow by 40% to 50% by 2030
- Coincidentally, crude supplies increasingly concentrated in OPEC/ politically unstable geographies
- Coal offers opportunity to diversify worldwide liquid fuel supplies

Coal-to-Liquids – Part of an Unconventional Fuels Portfolio

- Growing consensus on need to diversify transportation fuel sector
  - Long term: hydrogen
  - Intermediate term: liquids from coal, oil shale, liquids from biomass, increased domestic petroleum production, efficiency
- Advantages of Coal and CTL Technology
  - U.S. coal reserves amount to 250-year supply at current rates of consumption
  - Coal resources are dispersed (proven reserves in 26 states)
  - 1 ton of coal can be processed into 2 barrels of high-quality liquid fuels
  - Offers opportunity to pre-invest in eventual hydrogen-from-coal production facility

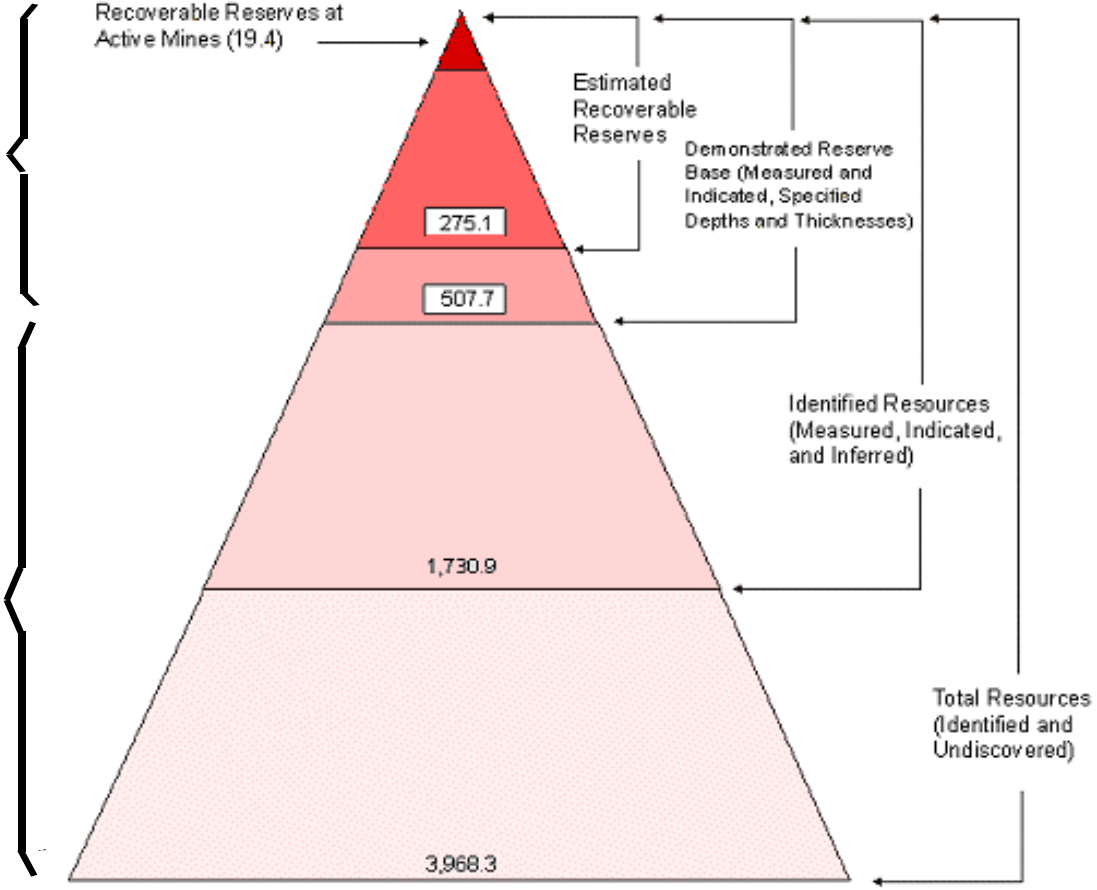
The U.S. Leads in Coal Reserves



Source: Energy Information Administration, World Recoverable Coal Reserves

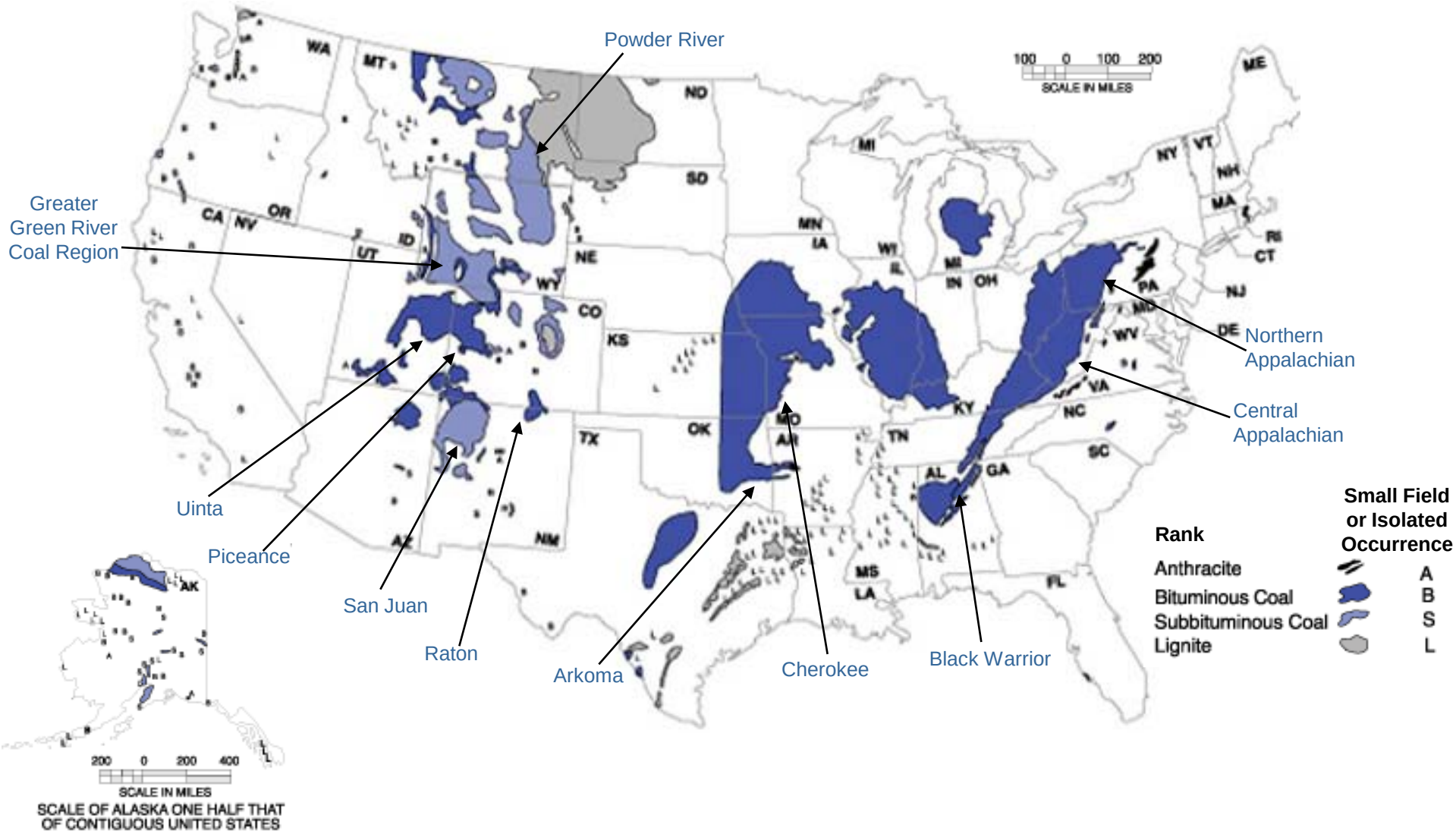
Delineation of U.S. Coal Reserves and Resources

- **RESERVES – quantities of coal anticipated to be commercially recoverable from known accumulations from a given date forward under defined conditions.**
- **RESOURCES – quantities of coal estimated, as of a given date, to be potentially recoverable from known accumulations, but which are not currently considered commercially recoverable.**
- **There is sufficient reserve to meet projected demand for electricity and up to 4MM bpd CTL industry for over 100 years**

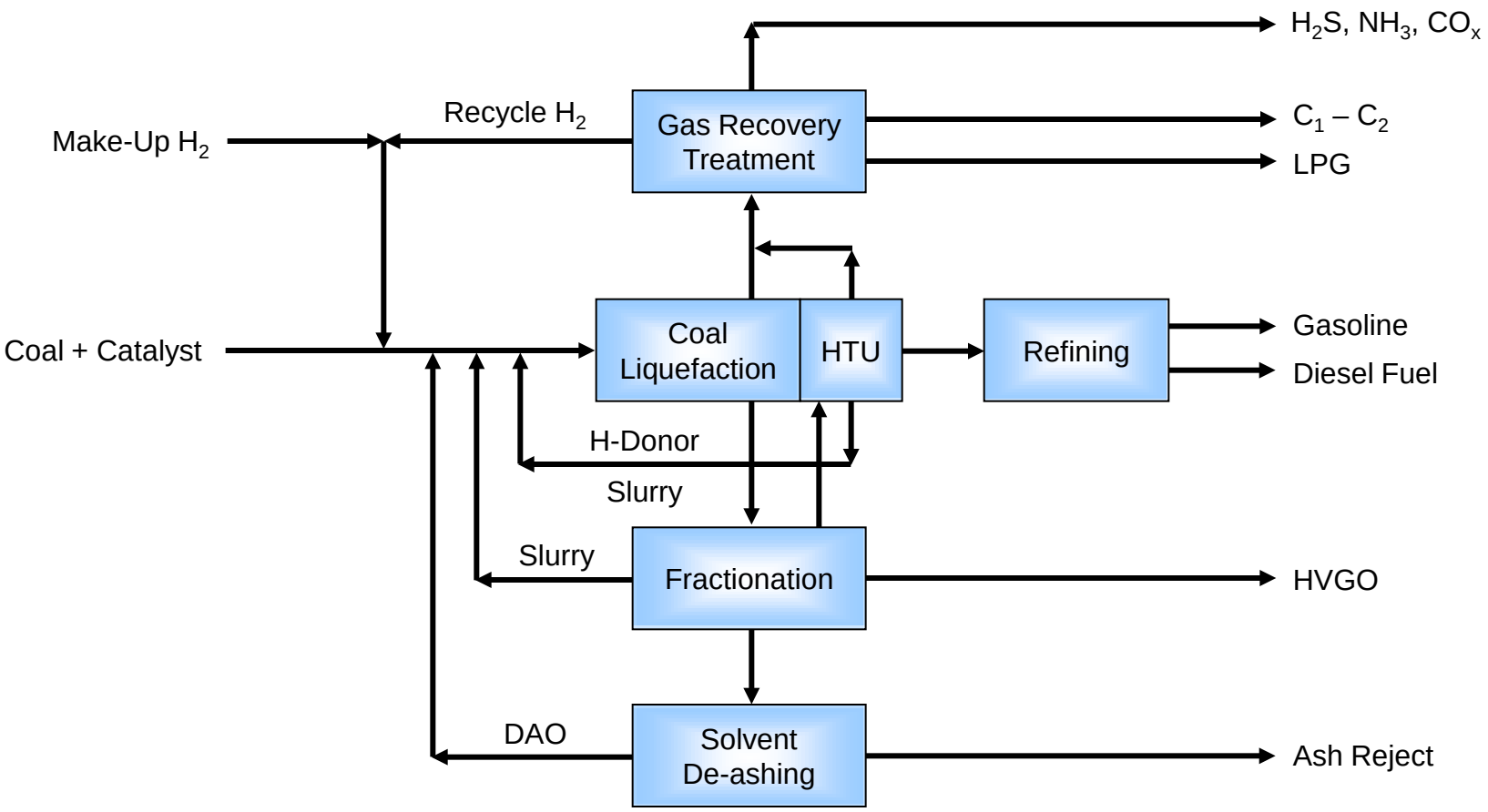


Source: EIA Coal Reserves Data 1997

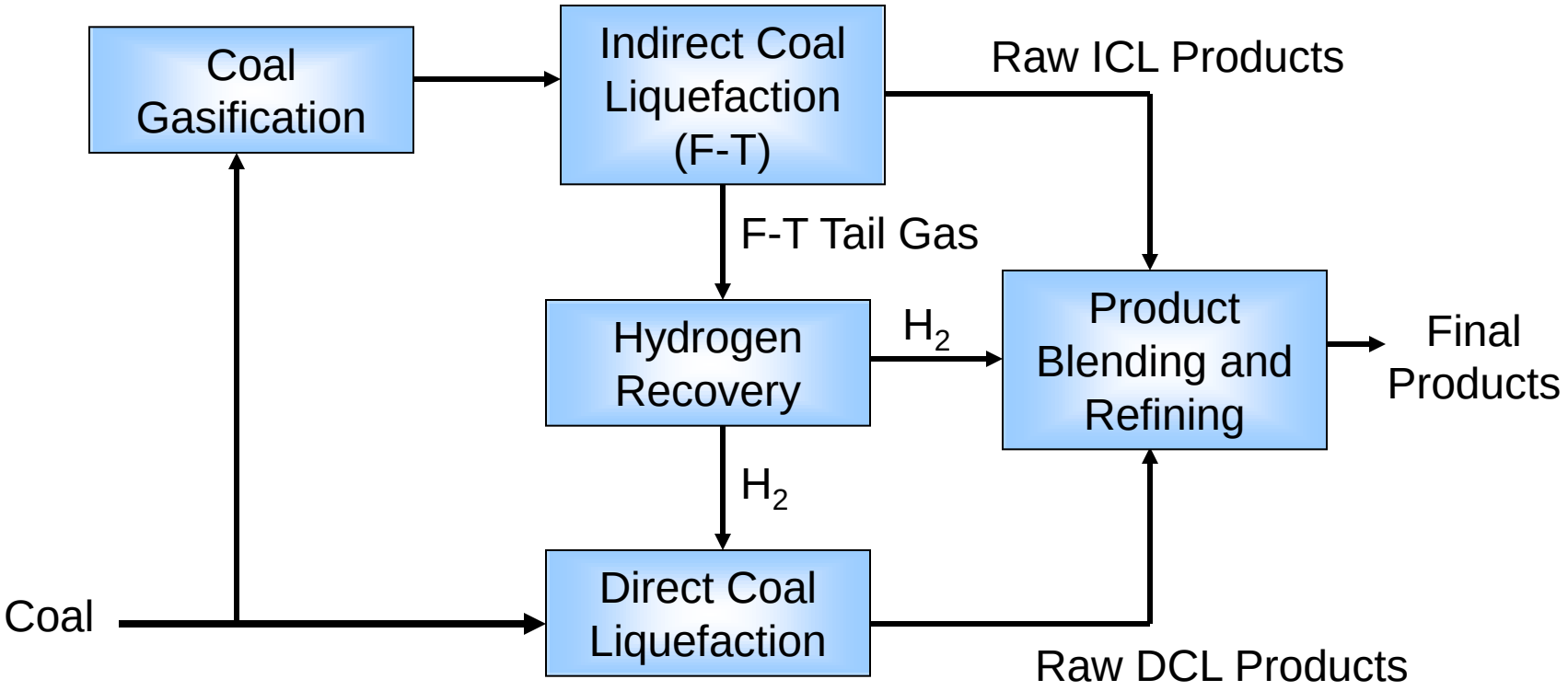
U.S. Coal Reserves Distribution



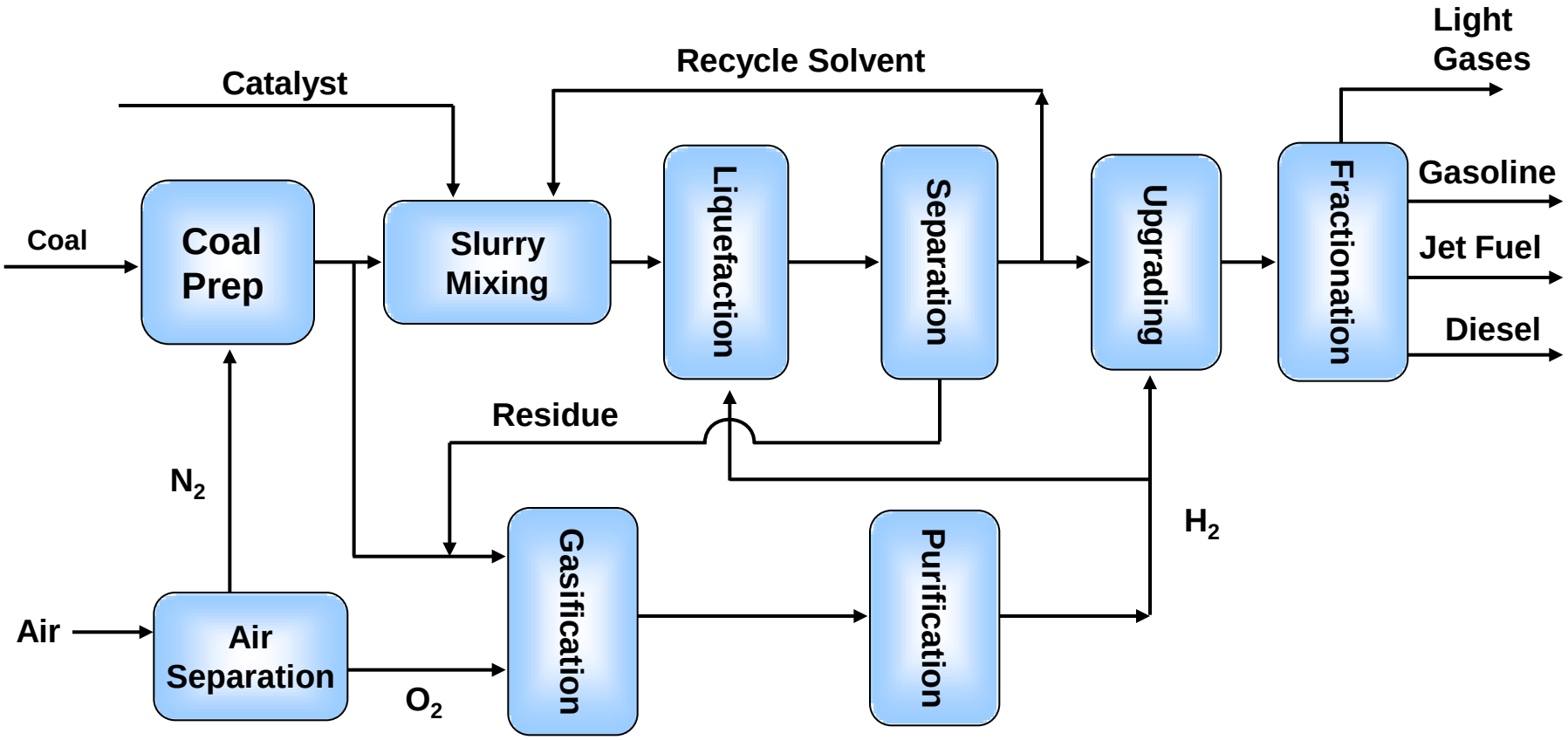
Direct Coal Liquefaction Process



Hybrid DCL/ICL Plant Concept

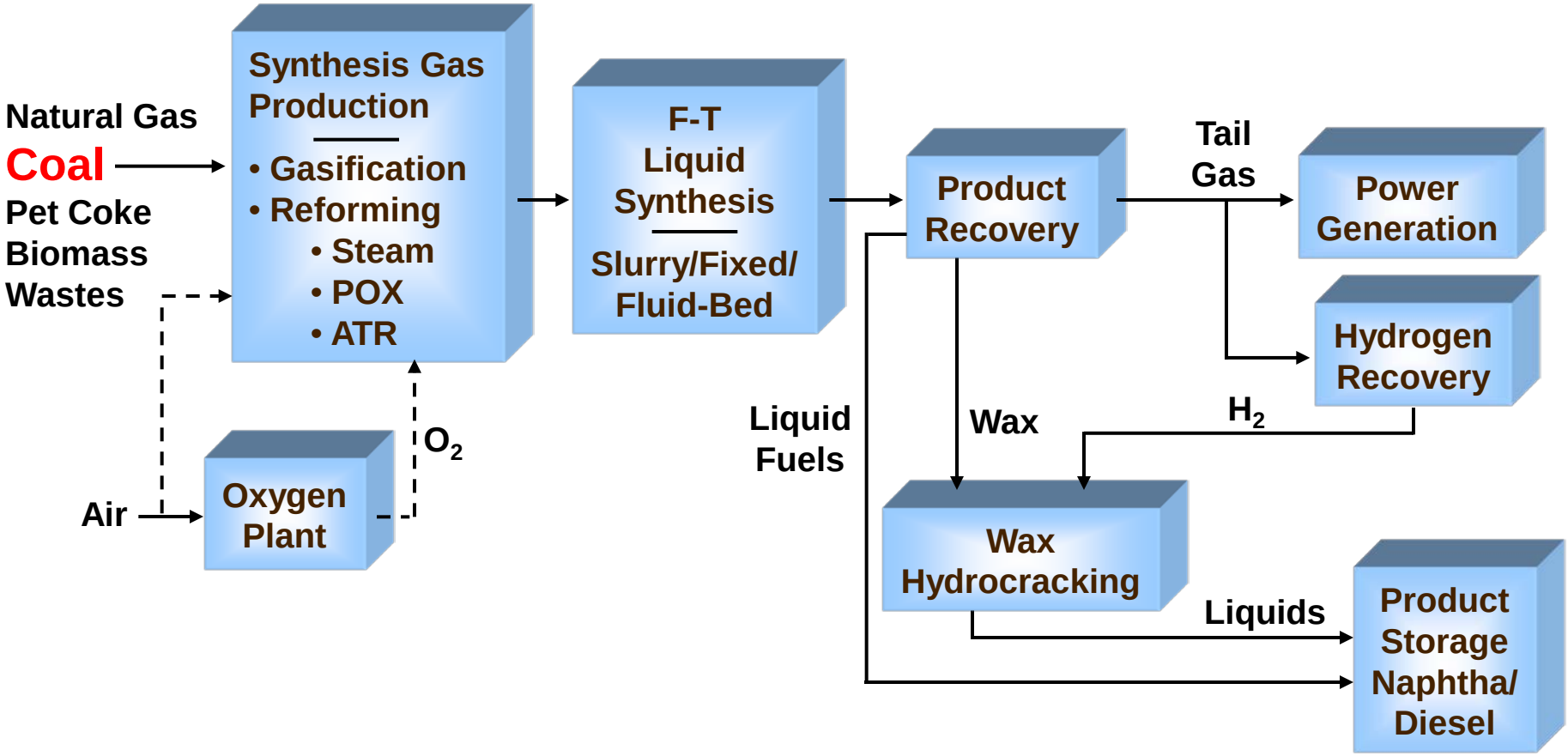


Shenhua DCL Process



First Train: 1 MT/a Liquefaction Oil

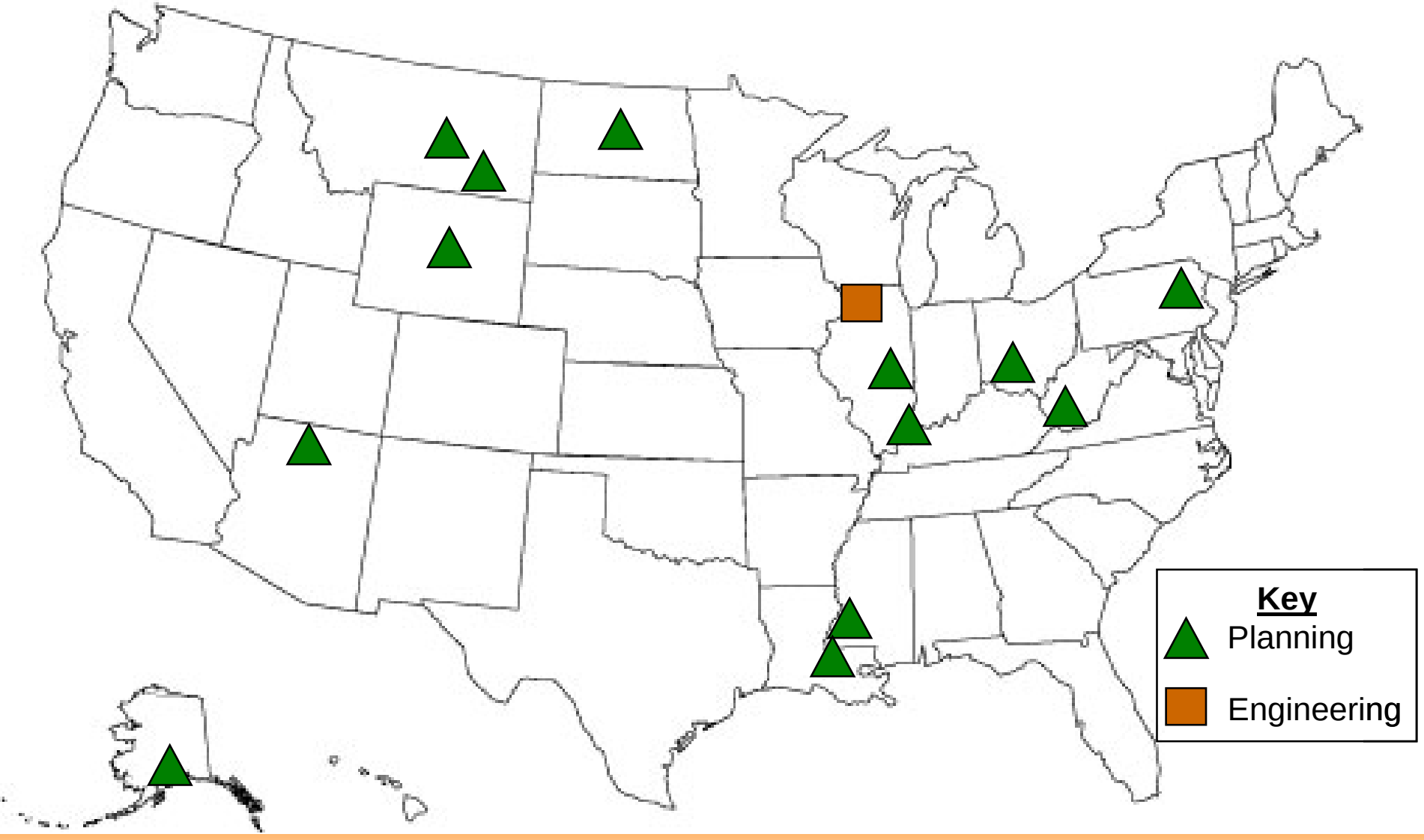
Indirect Coal Liquefaction Overview



Coal-To-Liquids: Current Status

- Costs – many systems analyses ongoing; for 50,000 bpd plant:
  - Capital costs estimated at $3.5–4.5 billion
  - Product cost at $40/bbl
- Technology considered commercial
  - DOE/industry completed program for development of direct liquefaction technology
  - Sasol producing 150,000 bpd of F-T products
  - Shenhua China Coal Liquefaction Corp. constructing 20,000 bpd plant; additional 180,000 bpd planned
  - Shenhua supports feasibility studies for two 80,000 bpd coal-to-liquid plants
  - Improved processes, catalysts, and slurry reactors available
  - Bench and pilot facilities at Rentech, Headwaters, Syntroleum, and ConocoPhillips

Location of Proposed CTL Projects in the United States

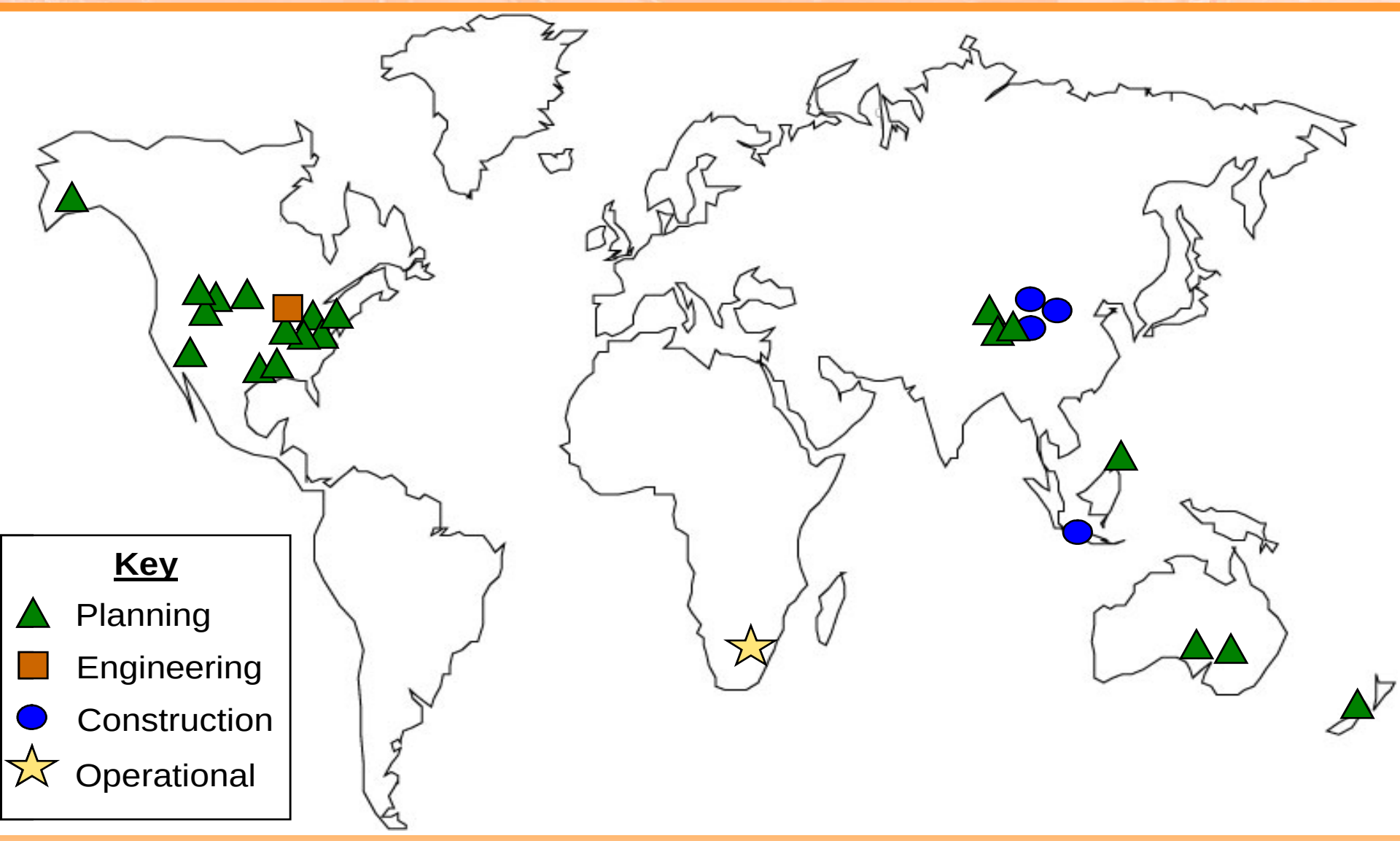


Coal-to-Liquids Plants Under Consideration in the United States

Project Lead	Project Partners	Location	Feedstock	Status	Capacity	Cost
American Clean Coal Fuels	None cited	Oakland, IL	Bituminous	Feasibility	25,000	N/A
Synfuels Inc.	GE, Haldor-Topsoe, NACC, ExxonMobil	Ascension Parish, LA	Lignite	Feasibility	N/A	$5 billion
DKRW Advanced Fuels	Rentech, GE	Medicine Bow, WY	Bituminous	Design (2011)	13,000 bpd	$1.4 billion
DKRW Advanced Fuels	Rentech, GE, Bull Mountain Land Company	Roundup, MT	Sub-bituminous/ Lignite	Feasibility	22,000 bpd	$1–1.5 billion
AIDEA	ANRTL, CPC	Cook Inlet, AK	Sub-bituminous	Feasibility	80,000 bpd	$5–8 billion
Mingo County	Rentech	WV	Bituminous	Feasibility	20,000 bpd	$2 billion
WMPI	Sasol, Shell, DOE	Gilberton, PA	Anthracite	Design	5,000 bpd	$612 million
Rentech/Peabody	N/A	MT	Sub-bituminous/ lignite	Feasibility	10,000–30,000 bpd	N/A
Rentech/Peabody	N/A	Southern IL, Southwest IN, Western KY	Bituminous	Feasibility	10,000–30,000 bpd	N/A
Rentech*	Kiewit Energy Company, WorleyParsons	East Dubuque, IL	Bituminous	Construction (2010)	1,800 bpd*	$800 million
Rentech	Adams County	Natchez, MS	Coal/Petcoke	Feasibility	10,000 bpd	$650–750 million
Rentech	Baard Energy	Wellsville, OH	Sub-bituminous	Feasibility	35,000 bpd	$4 billion
Headwaters	Hopi Tribe	AZ	Bituminous	Feasibility	10,000–50,000 bpd	N/A
Headwaters	NACC, GRE, Falkirk	ND	Lignite	Feasibility	40,000 bpd	$3.6 billion

*Co-producing fertilizer

CTL Projects Worldwide



International CTL Plants and Projects

Country	Owner/Developer	Capacity (bpd)	Status
South Africa	Sasol	150,000	Operational
China	Shenhua	20,000 (initially)	Construction Operational in 2007–2008
China	Lu'an Group	~3,000–4,000	Construction
China	Yankuang	40,000 (initially) 180,000 planned	Construction
China	Sasol JV (2 studies)	80,000 (each plant)	Planning
China	Shell/Shenhua	70,000–80,000	Planning
China	Headwaters/UK Race Investment	Two 700-bpd demo plants	Planning
Indonesia	Pertamina/Accelon	~76,000	Construction
Australia	Anglo American/Shell	60,000	Planning
Australia	Altona Resources plc, Jacobs Consultancy, MineConsult	45,000	Planning
Philippines	Headwaters	50,000	Planning
New Zealand	L&M Group	50,000	Planning

Congressional Interest in CTL

- Previous Congress (109th)
  - H.R. 4761 – Deep Ocean Energy Resources Act of 2006
  - H.R. 5965 – Progress Act
  - H.R. 5653 – Investment in American Energy Independence Act of 2006
  - H.R. 5890 – American-Made Energy Trust Fund Bill
  - S. 1920 – Renewable Diesel Standard Act of 2005
  - S. 2446 – American Fuels Act of 2006
  - S. 3325 – Coal-to-Liquid Fuel Promotion Act of 2006
- Current Congress (110th)
  - S. 154
  - S. 155
  - H.R. 370

  } Coal-to-Liquid Fuel Promotion Act of 2007

Reports and Studies – CTL Processes

- Department of Defense
  - OSD Assured Fuels Initiative
  - Flight Test of F-T Jet Fuel Blend
  - Air Force Energy Industry Forum
- Mitretek
  - Techno-Economic Analysis of Wyoming Located CTL Plant
  - Gasification of Kemmerer Coal at the Mine Mouth in Wyoming for Production of Zero Sulfur Liquid Transportation Fuels and Electric Power: A Feasibility Study
  - Clean Transportation Fuels from Domestic Coal
- National Coal Council
  - America's Energy Future
- Southern States Energy Board
  - American Energy Security Study
- Scully Capital Services, Inc.
  - The Business Case for Coal Gasification with Co-Production

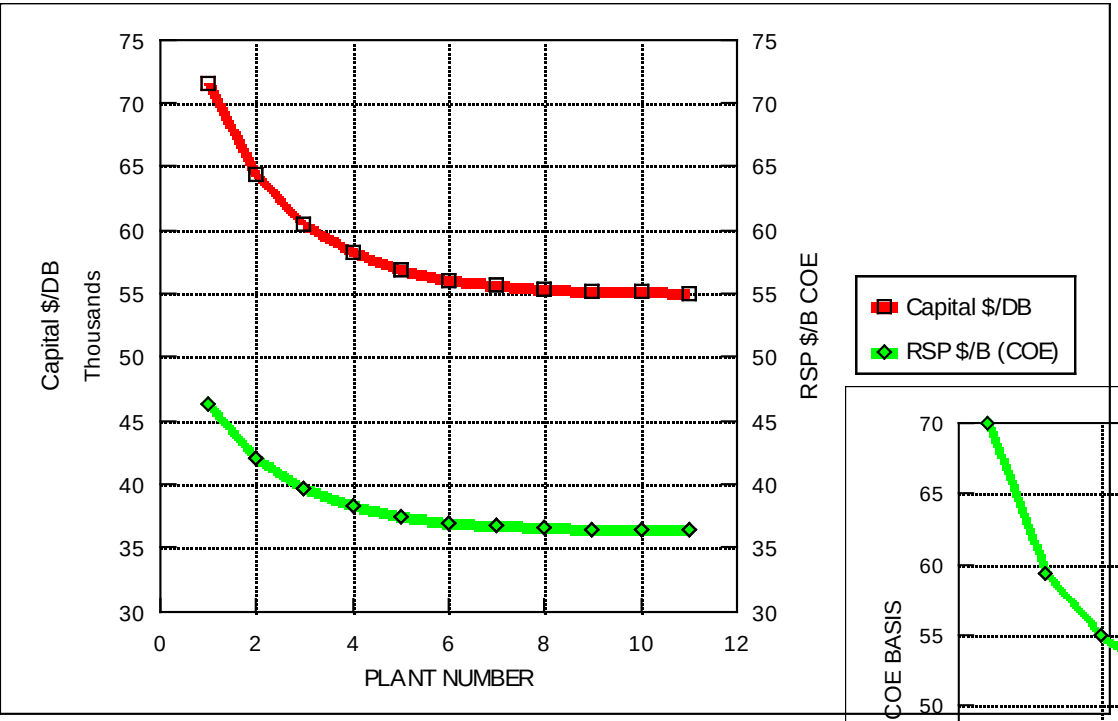
Reports and Studies – CTL Processes (continued)

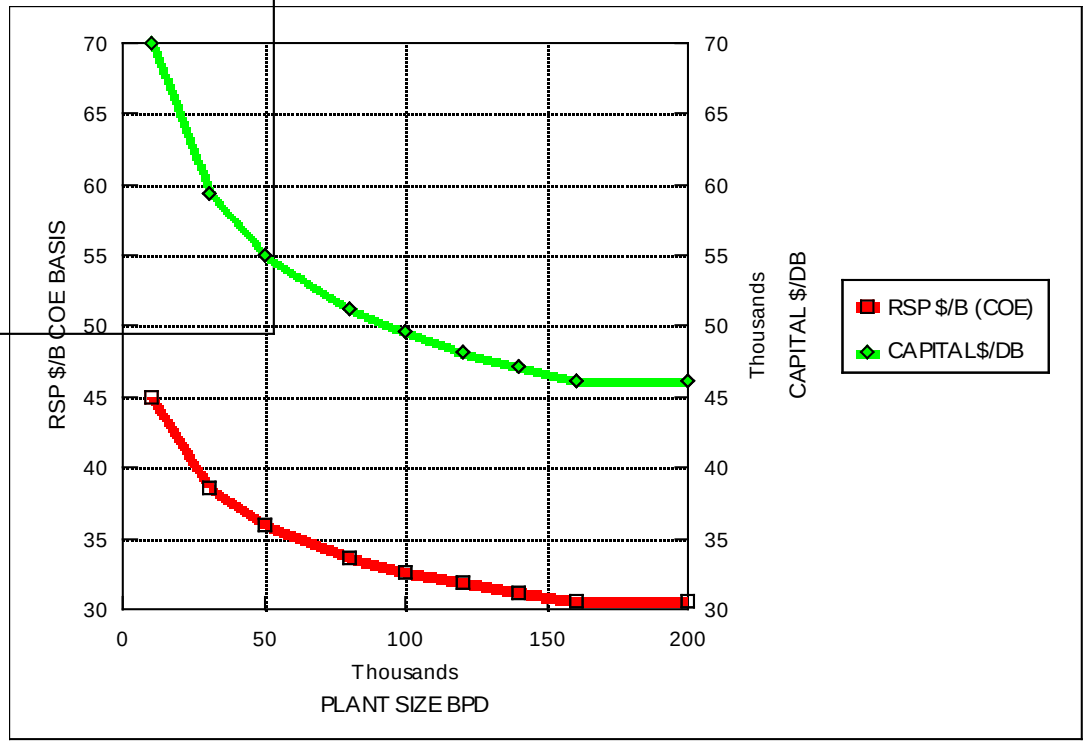
- Conference Report 109-360 - National Defense Authorization Act for Fiscal Year 2006
  - A Development Plan for a Coal-to-Liquid Fuel Program
- Energy Policy Act - 2005, Section 369
  - Commercialization of America's Strategic Unconventional Fuels: Oil Shale • Tar Sands • Coal Derived Liquids • Heavy Oil • CO_2 Enhanced Recovery and Storage
- Rand Corporation
  - Unconventional Fuels: Strategic and Program Options
- World Coal Institute
  - Coal: Liquid Fuels

CTL Technology – Economics Remain Key Issue

- Conceptual plant designs estimate $3.5–4.5 billion required for initial 50,000-bpd plants (Capital cost = $70–90K/daily barrel)
- Plants may be profitable with crude oil price between $45–60/bbl with carbon storage (carbon storage estimated to account for $4/barrel of the required selling price)
- Higher unit investment costs for pioneer demonstration plants (10,000- to 20,000-bpd plants)
- Difficult to accurately estimate costs since no plants have been built worldwide since the 1980s

Potential Impacts on Cost





Barriers to Coal-To-Liquids

- Technical
  - Integrated operations of advanced CTL technologies have never been demonstrated
- Economic
  - Uncertainties about future world oil production
  - High capital and operations costs
  - Investment risks
  - Energy price volatility
- Environmental
  - CO_2 and criteria pollutant emissions
  - Expansion of coal production and requisite infrastructure (railroads, railcars, etc.)
  - Water use
- Commercial Deployment
  - Competition for critical process equipment, engineering, and skilled labor
  - Who would take the lead in commercial deployment? Part power part liquid fuels
- Social
  - NIMBY and public resistance to coal use