Clean Coal Gasification, FT Process Design and Implementation

Clean Coal for Transportation Fuels Workshop

Purdue University

December 2, 2005

Michael E. Reed, Systems Analyst, Office of Systems, Analyses, and Planning

National Energy Technology Laboratory

Office of Fossil Energy

National Energy Technology Laboratory

- **Only U.S. Department of Energy national lab dedicated to fossil energy**
  - Fossil fuels provide 85% of U.S. energy supply
- **One lab, four locations, one management structure**
- **1,100 Federal and support-contractor employees**
- **Research spans fundamental science to technology demonstrations**

Pennsylvania

West Virginia

Alaska

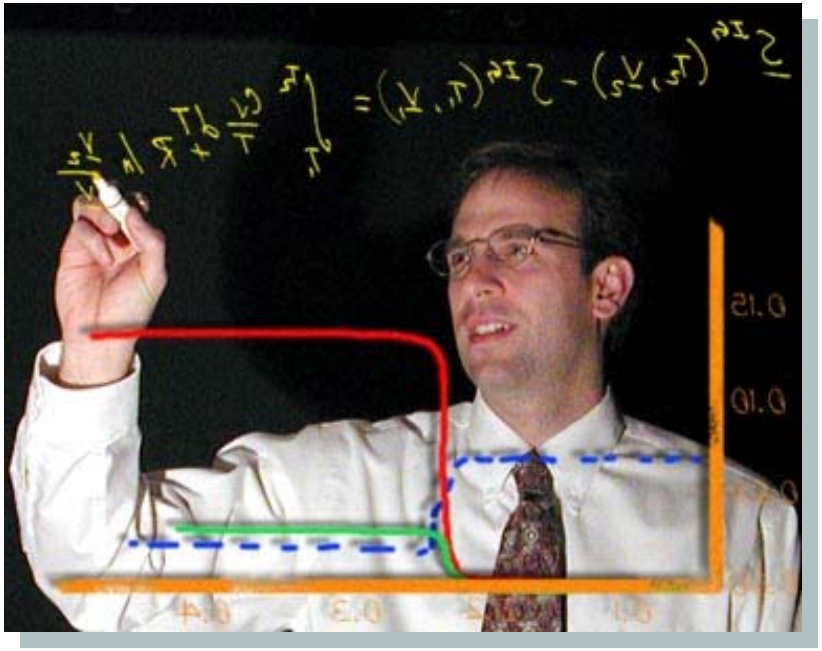
Oklahoma

NETL's Mission

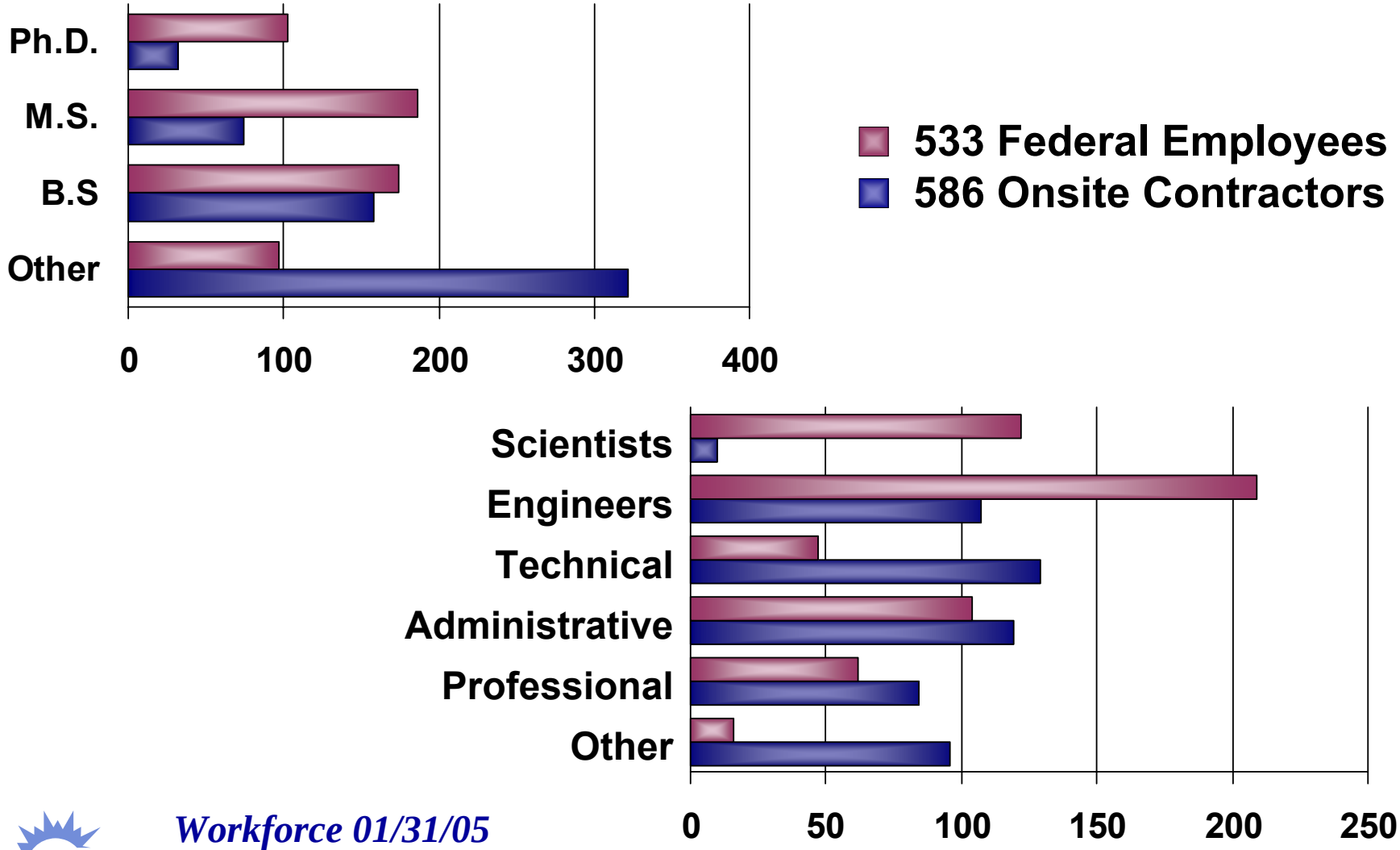
Implement a research, development, and demonstration program to resolve the environmental, supply, and reliability constraints of producing and using fossil resources

Accomplishing Our Mission

- Implement and manage extramural RD&D
- Conduct intramural research
- Support energy policy development



A Well-Trained Workforce



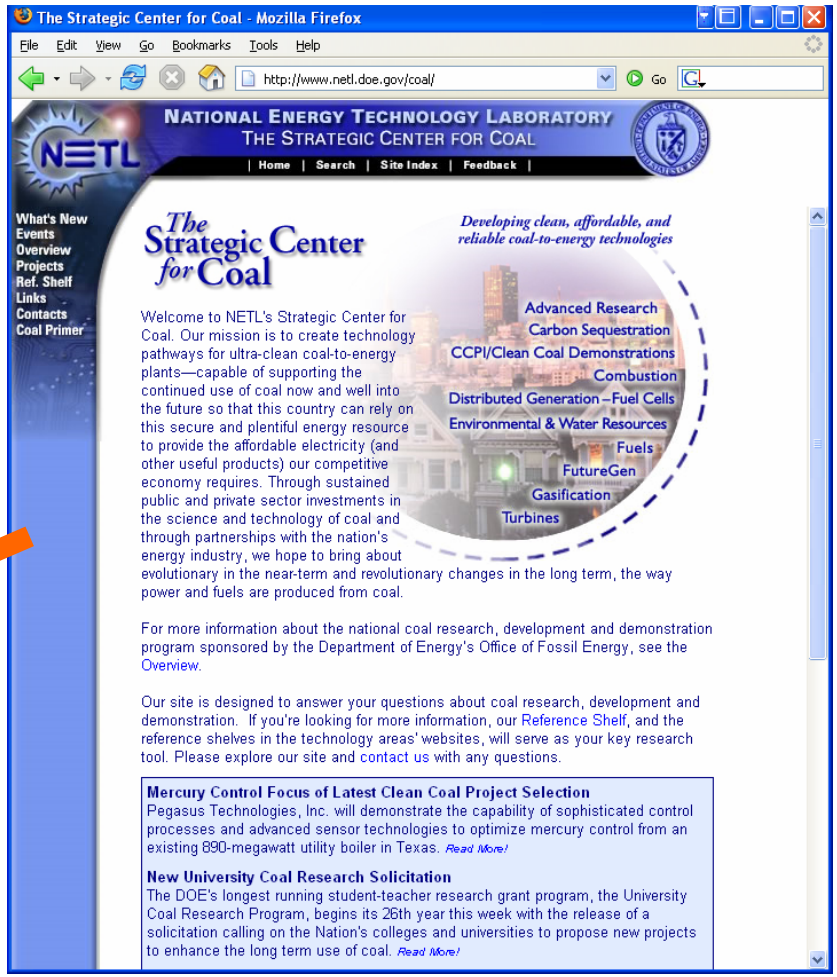
Workforce 01/31/05

Visit Our NETL Website

www.netl.doe.gov

Visit Our SCC Website

www.netl.doe.gov/coal/

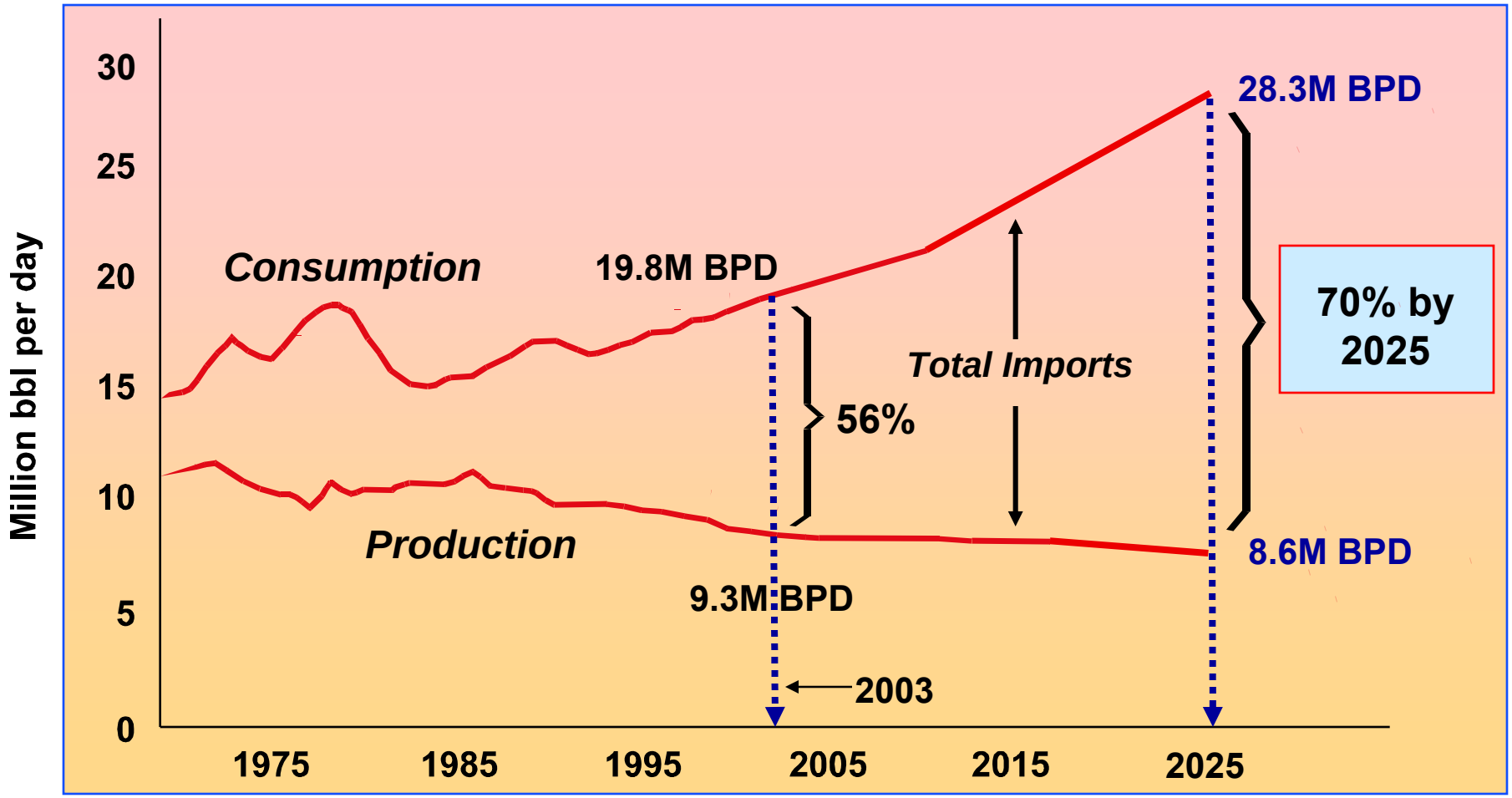


Excerpts from April 05 Presidential Speech

- "We now import more than half our oil from abroad…in order to maintain our lifestyles, and our dependence is growing. I believe that creates a national security issue and an economic security issue for the United States. And that is why it is important for us to utilize the resources we have here at home in environmentally friendly ways."
- "Increasing our energy security begins with a firm commitment to America's most abundant energy source – and that is COAL….it should be at the heart of America's energy strategy"
  - **52% electric power from coal currently**
  - **Long term hydrogen from coal with CCS**

Mid term CTL?

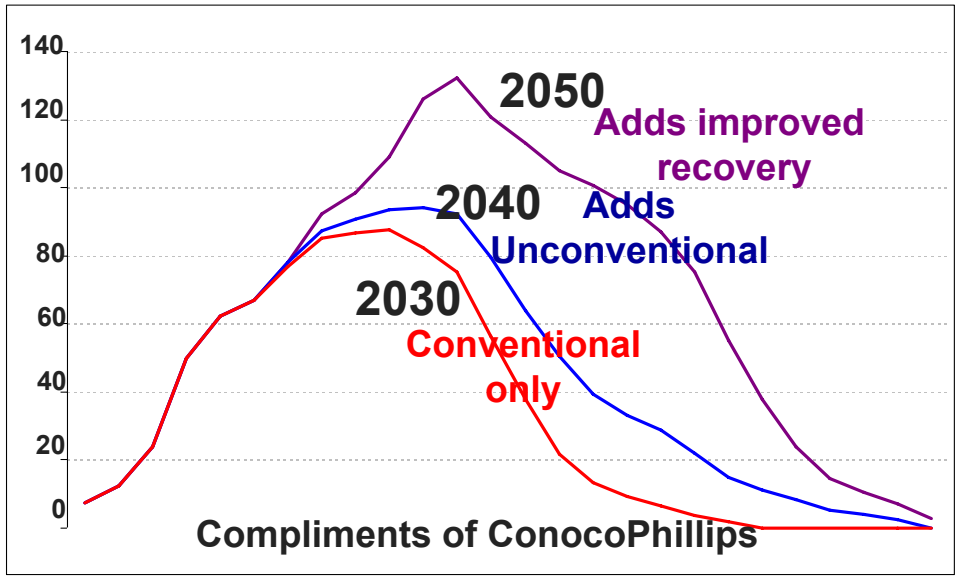
U.S. Production, Consumption, and Total Imports of Petroleum (1970-2025)



Source: EIA (AEO 2005), Reference Case Scenario

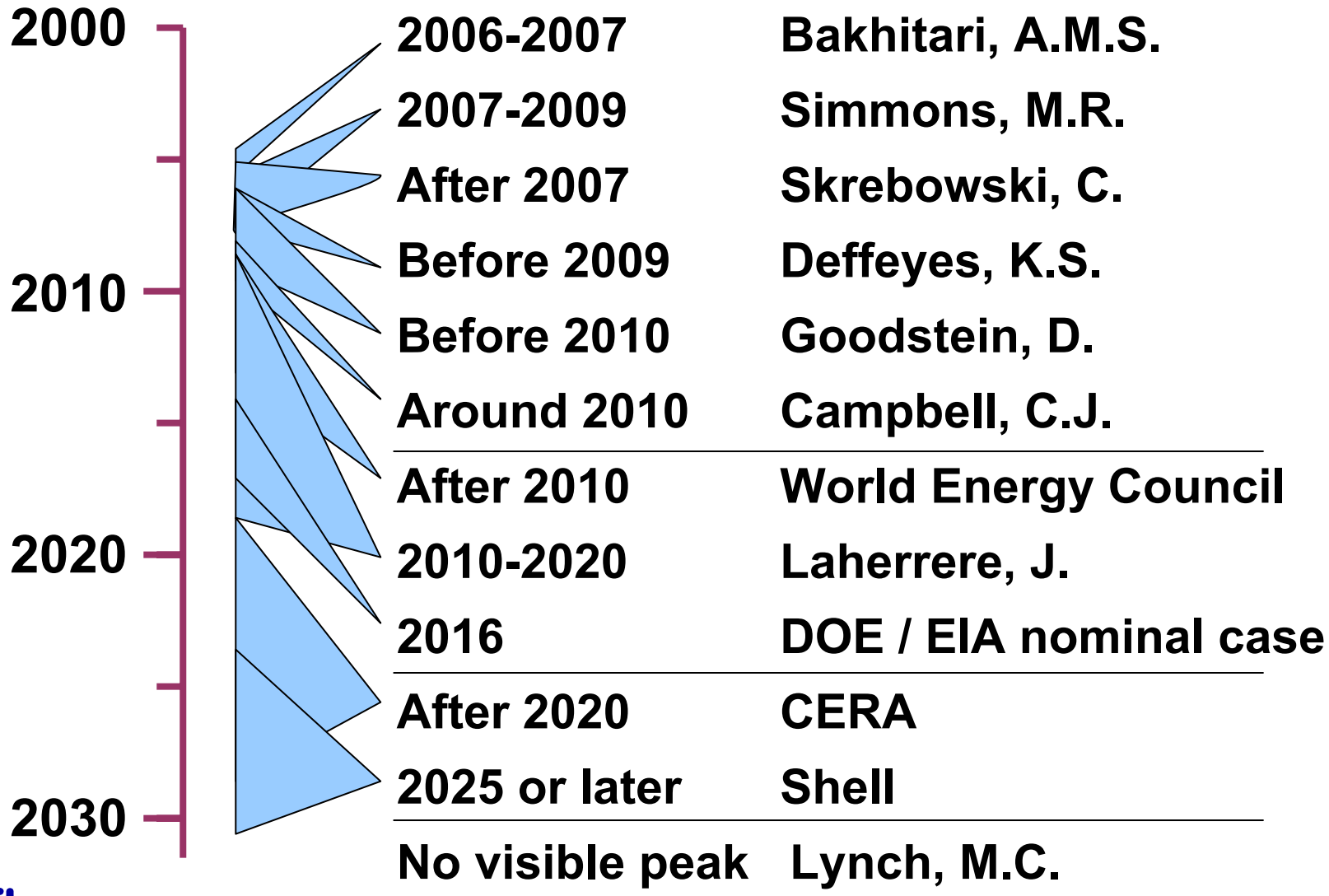
One Oil Peaking Scenario

Oil Production in Million Barrels per Day



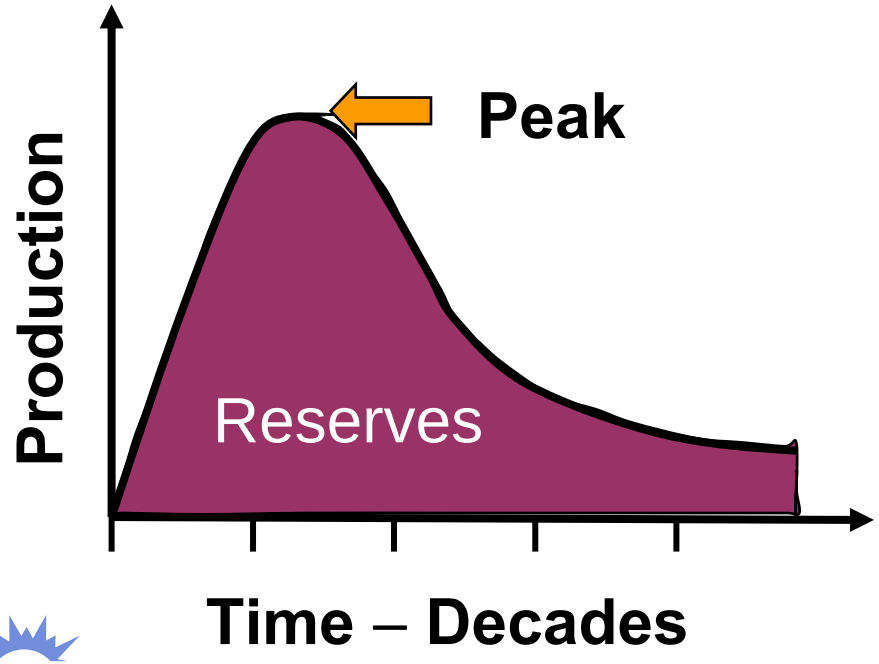
Sources:
USGS Estimates of Total Recoverable Resources: 1981 – 2000
Peter R. Odell, Erasmus University Rotterdam; COP estimate

Recent Projections Of World Oil Peaking



No Question World's Conventional Oil Production Will Peak

Production curve from typical oil reservoir thought applicable to total world production

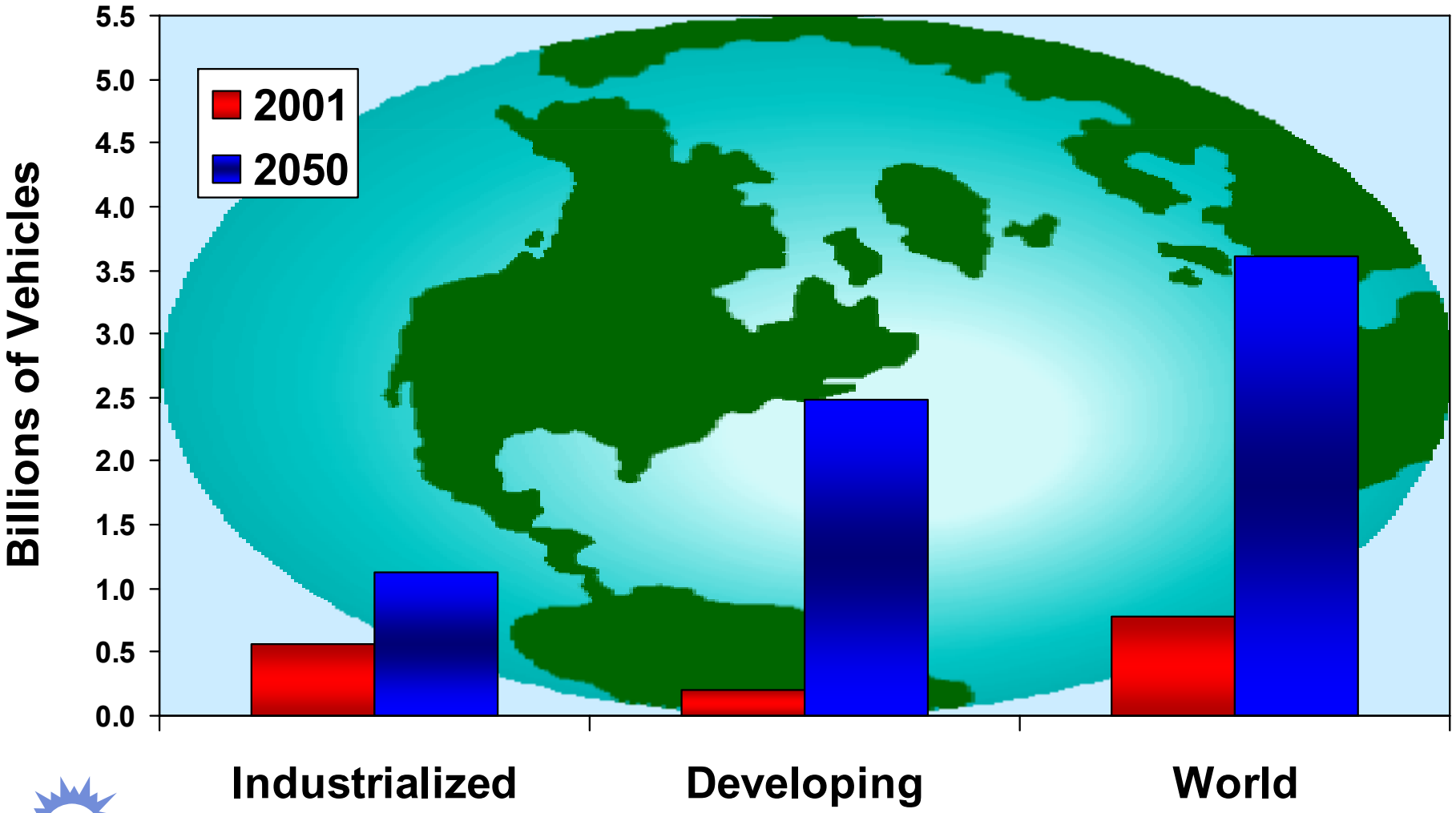


- **Peaking ≠ running out**
  - Maximum production
  - ~ Halfway to depletion

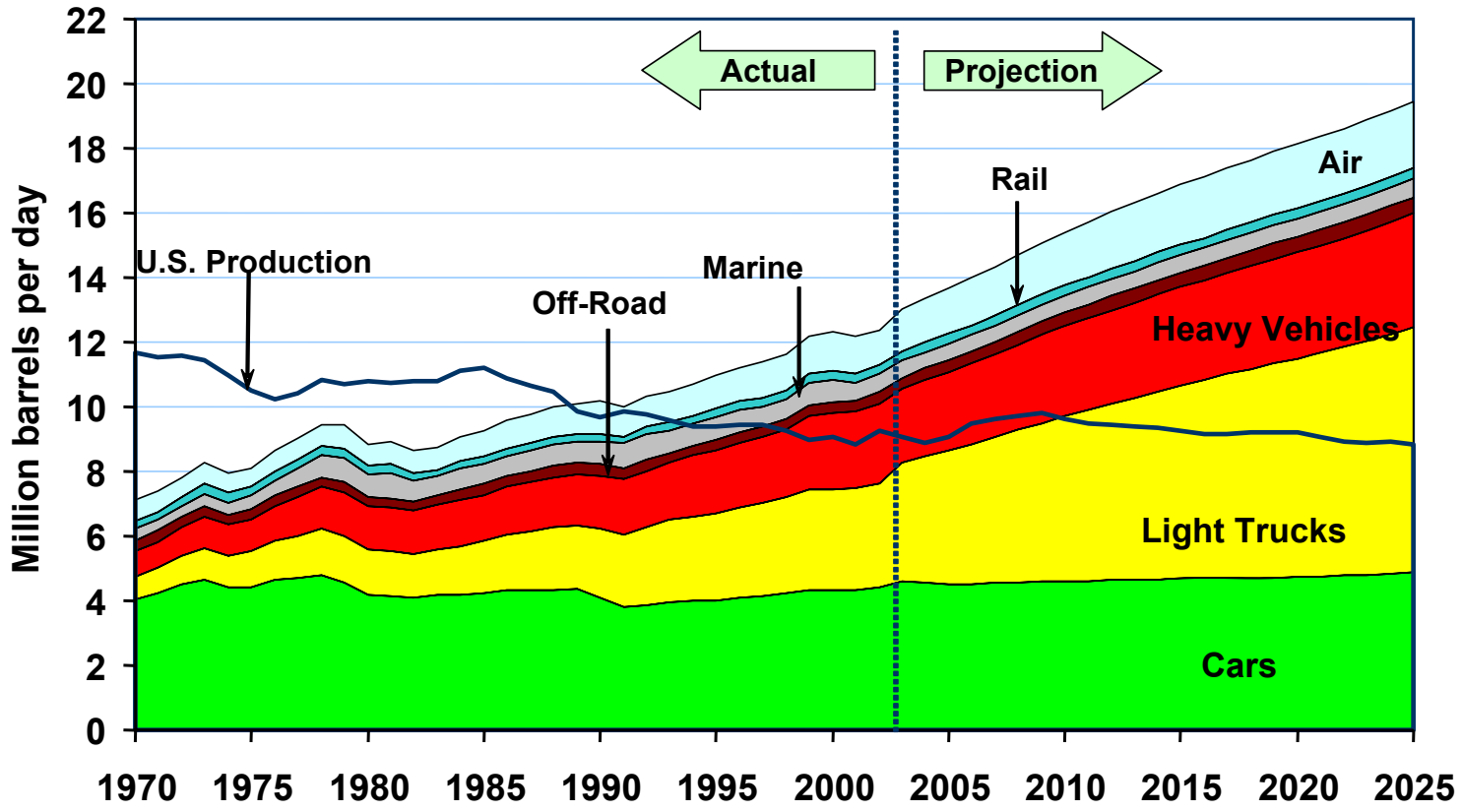
Conventional Oil Found in Discrete "Packets"

Reservoirs of all sizes, depths, & characteristics in limited number of places in world

Number of Vehicles is Increasing



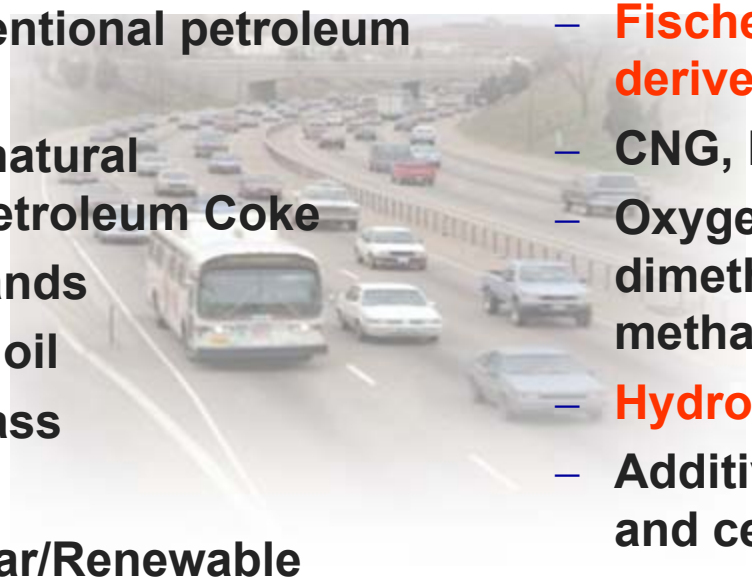
Energy Demand and Dependence on Fossil Fuels in the U.S. is driven by transportation sector



Note: Domestic production includes crude oil, natural gas plant liquids, refinery gain, and other inputs. This is consistent with EIA, MER, Table 3.2. Previous versions of this chart included crude oil and natural gas plant liquids only.
Source: Transportation Energy Data Book: Edition 24, ORNL-6973, and EIA Annual Energy Outlook 2005, Preliminary release, December 2004.

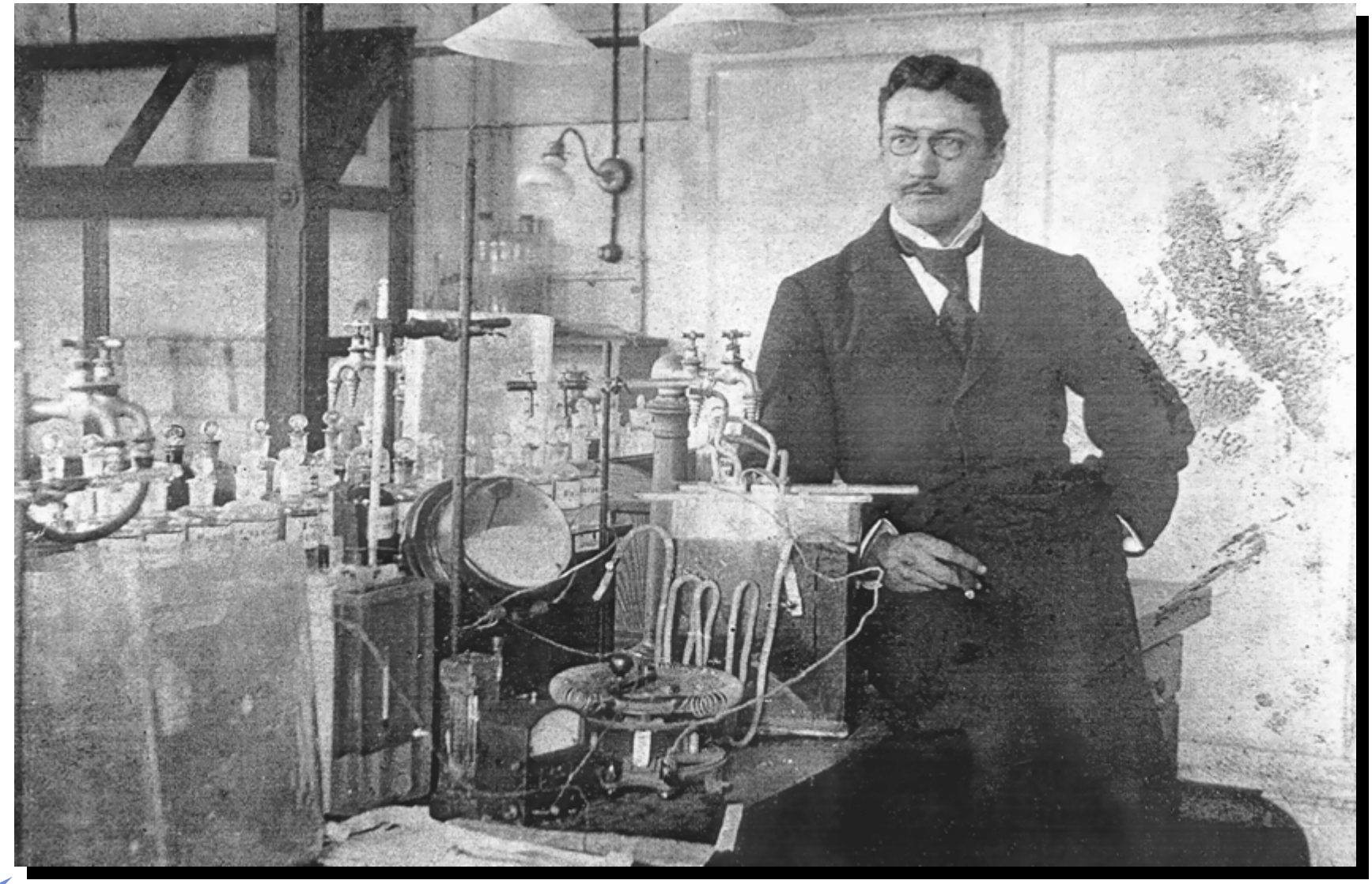
Diverse Resources and Fuel Options Will be Needed to Meet Future Transportation Needs

- **Resources**
  - Conventional petroleum crude
  - Coal/natural gas/petroleum Coke
  - Tar sands
  - Shale oil
  - Biomass
  - Water
  - Nuclear/Renewable



- **Fuels/Blendstocks**
  - Petroleum-derived fuels
  - Fischer-Tropsch (F-T)-derived fuels
  - CNG, LNG
  - Oxygenates, e.g. dimethyl ether (DME), methanol, ethanol
  - Hydrogen
  - Additives, e.g., octane and cetaner improvers
  - Electricity

Franz Fischer at Work in 1918



Financial Mail, 2000

Why Coal-to Liquids (CTL)?

- Energy Security:
  - **Large domestic coal resource (250 years supply) could increase domestic transportation fuel production and reduce oil imports**
- Advances have been made in Gasification through IGCC deployment
- Advances made in F-T Synthesis step through catalyst/reactor research
- Fuels produced are compatible with existing liquid fuels infrastructure
- F-T product can be easily upgraded to specification fuel at production site; only the naphtha fraction (25% or less) requires conventional refining

CTL: Current Status

- **Gas to Liquids (GTL) is commercial**
  - Approximately $25,000/bbl construction cost
  - Natural gas at $0.50-$1.0/ MM Btus
    -RSP ~ $20-25/BBL
  - Exxon-Mobil, Shell and Sasol plants planned in Qatar and Nigeria

- **Coal to Liquids technology**
  - Sasol 150,000 BPD FT plants in South Africa
    -China Shenhua Sasol feasibility studies for 2 large FT plants
  - China Shenhua direct liquefaction plant
  - No large scale integrated plants built with advanced technology
  - FE RD&D program developed direct and indirect CTL technologies
  - Improved processes, catalysts and slurry reactors, LPMeOH

F-T Product Premium

- **The high hydrogen content and absence of sulfur in F-T products should assure a premium in the $4-$6 range compared to a typical crude …atmospheric gas oil, a light refinery distillate, has a $3 premium over crude but still has sulfur.**

Barriers to CTL

- **Technical:**
  - Integrated operations of advanced CTL technologies have never been demonstrated
- **Economic:**
  - Uncertainties about future WOP
  - High Capital and operations costs
  - Investment risks
- **Environmental:**
  - CO_2 and criteria pollutants emissions
  - Expansion of coal production
- **Commercial Deployment:**
  - Competition for critical process equipment and engineering skills
    -Who would take the lead in commercial deployment? Part power part liquid fuels
- **Social:**
  - NIMBY & public resistance to coal use

Goals and Objectives - Gasification

- **By 2010, complete R&D for advanced gasification combined cycle technology that can produce electricity from coal at 45-50% efficiency (HHV) at a capital cost of $1,000/kWe or less (2002 $).**

- **By 2012, complete R&D to integrate this technology with CO_2 separation, capture, and sequestration into a zero-emission configuration(s) that can provide electricity with less than a 10 % increase in cost of electricity.**

- **By 2020, develop zero emission plants (including carbon) that are fuel-flexible and capable of multi-product output and efficiencies over 60% with coal.**

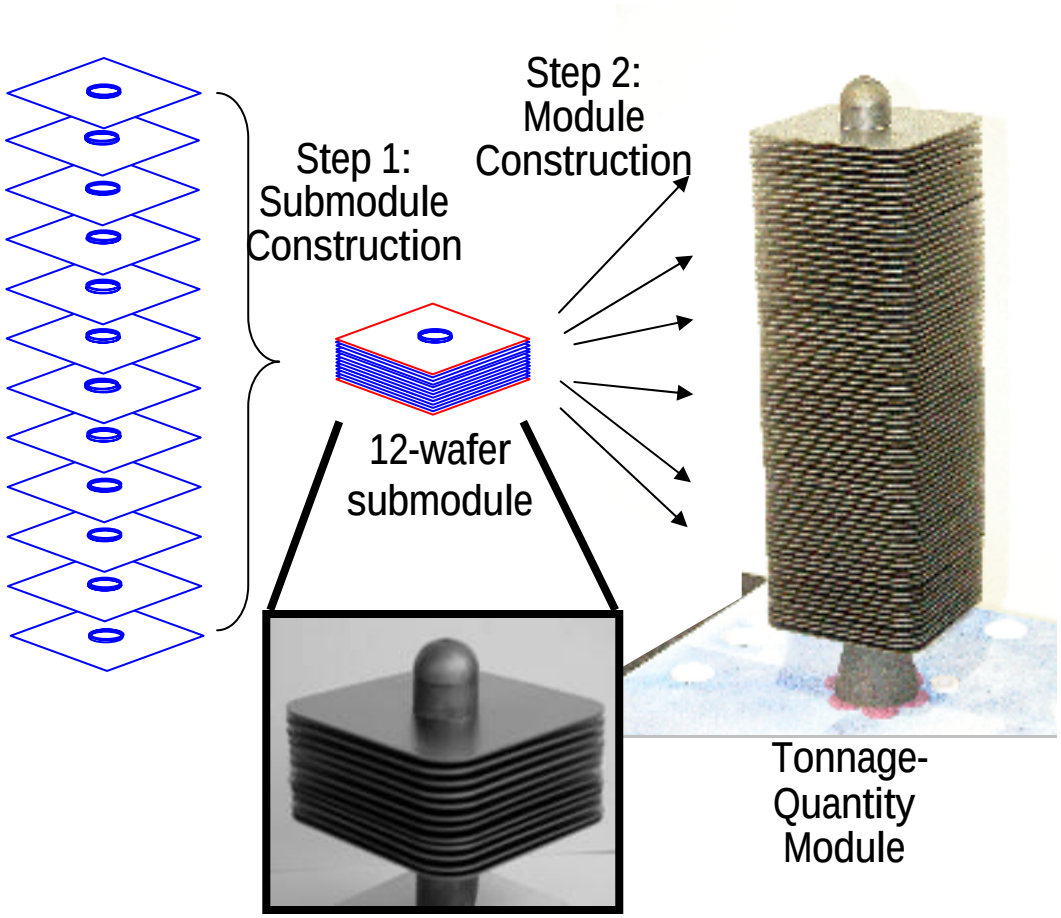
Gasification Systems

Southern Company

- EPRI
- Kellogg, Brown & Root
- Siemens Westinghouse Power
- Southern Research (SRI)
- Rolls Royce – Allison Engine
- Lignite Energy Council
- Peabody Coal
- BNSF Railway

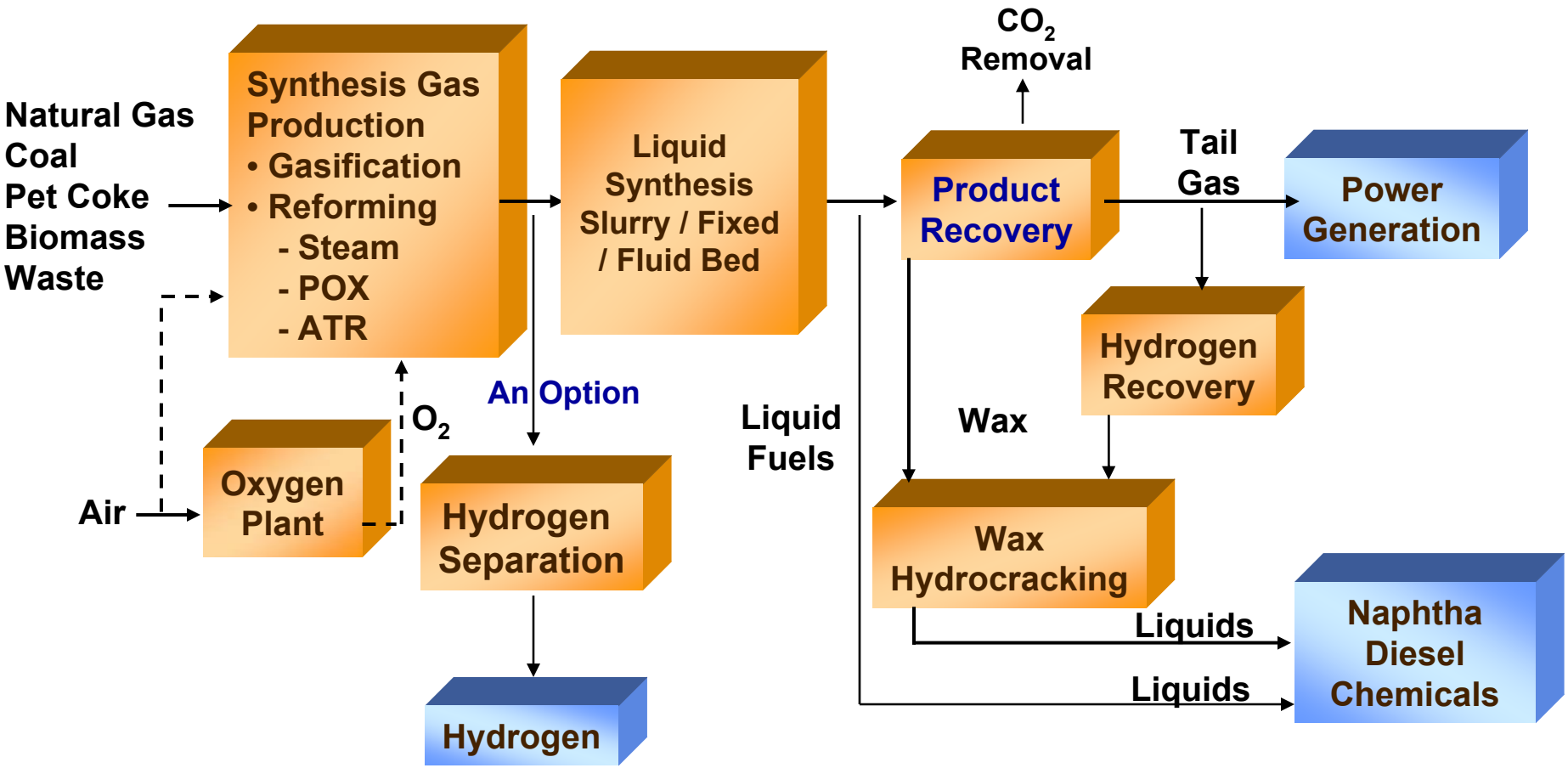
Development and demonstration of modular industrial scale gasification-based processes and components at Power Systems Development Facility (PSDF)

APCI Air Separation ITM Modules

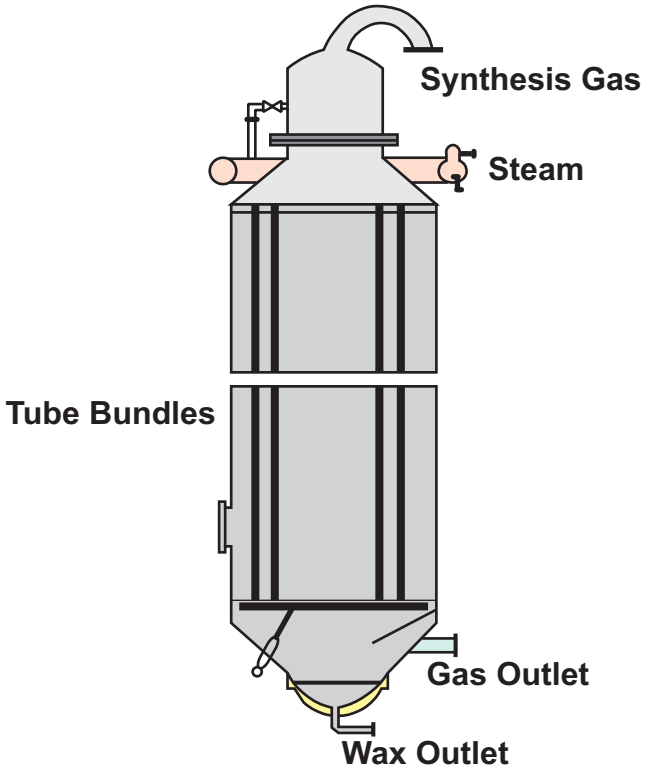


- **Test membrane modules**
  - FY06 – 5 TPD
  - FY08 – 25 TPD
- **Offer commercial air separation modules**
  - Post- FY09 demos of IGCC and FutureGen

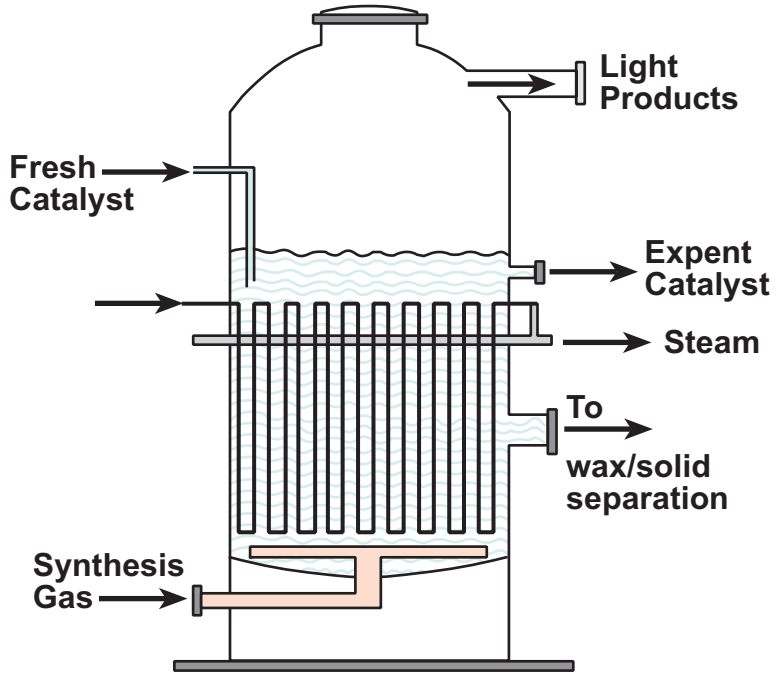
Co-production Technology Overview



Low Temperature FT Reactors



ARGE REACTOR



SLURRY BED REACTOR (SSBP)

I. Wender / Fuel Processing Technology 48, 1996

F-T Reactors
Advantages/Disadvantages

- Fixed Bed
  - **Easy to scale up**
  - **Simple to operate**
  - **Easy catalyst/product separation**
  - **Less susceptible to catalyst deactivation by sulfur**

- but -

  - **Very expensive to build**
  - **High pressure drop (high gas compression costs), which limits ability to use small sized catalyst (preferred for the F-T diffusion-controlled reaction**
  - **Very labor intensive catalyst replacement (every 70-100 days); each Arge reactor has 2,050 tubes, 5cm id and 12m long**
  - **Limited to low-temperature operation because carbon buildup plugs reactor**

Dry, 1996; Wender, 1996

F-T Reactors
Advantages/Disadvantages, Cont'd

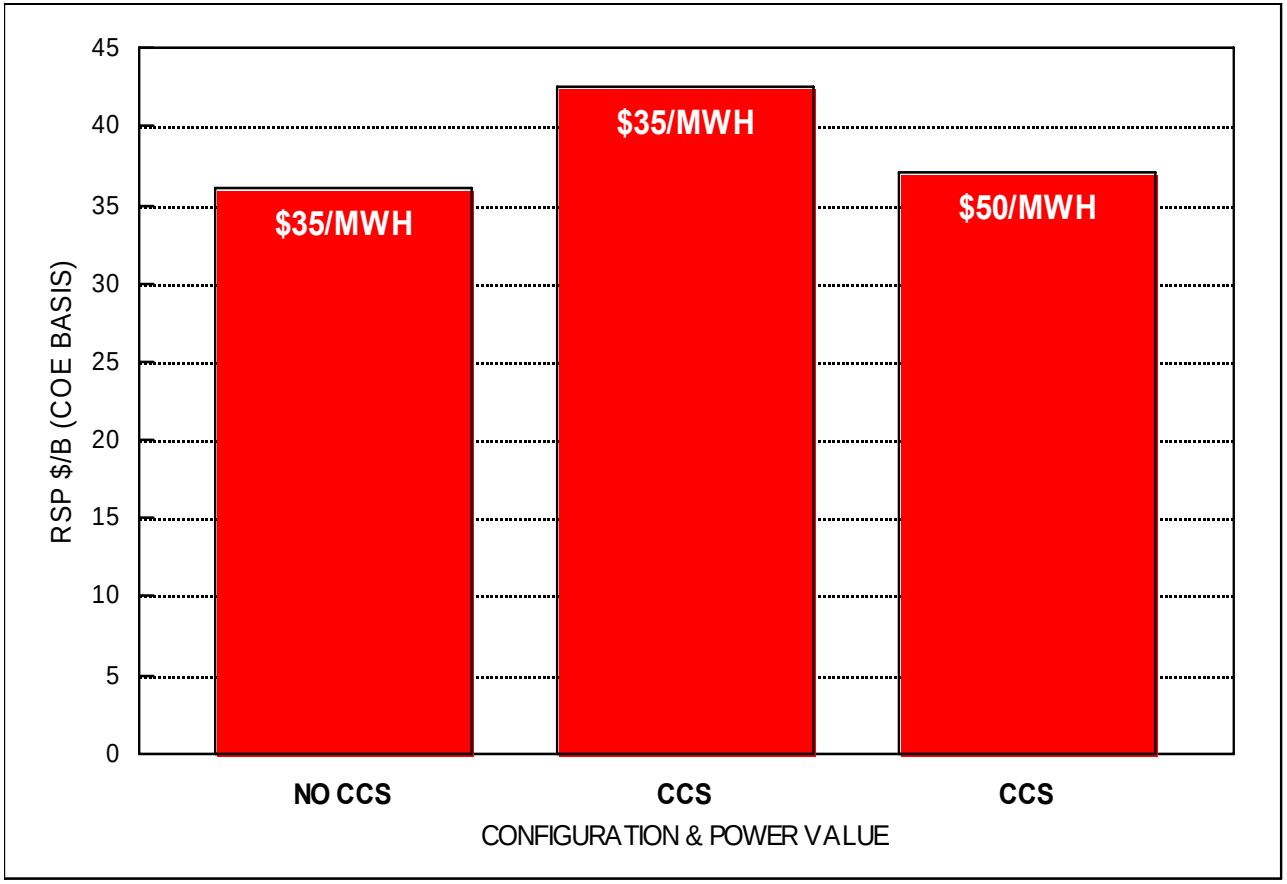
- Slurry Reactor (Three-Phase)
  - **Fairly easy to scale up and operate (potential single reactor capacity of 10,000 bbl/day)**
  - **~ 40% lower capital cost than fixed bed reactors**
  - **Much lower pressure drop than fixed bed units**
  - **Continuous catalyst replacement**
  - **Excellent heat removal capability -- can operate at higher temperatures than fixed bed -- capable of varying product mix**
  - **Can use very small catalyst particles, so higher catalyst activity per unit mass**

- but -

  - **More difficult than fixed bed to separate catalyst from wax product**
  - **Proper gas dispersion/bubble size is critical**

Dry, 1996; Wender, 1996

Polygeneration Economics Summary



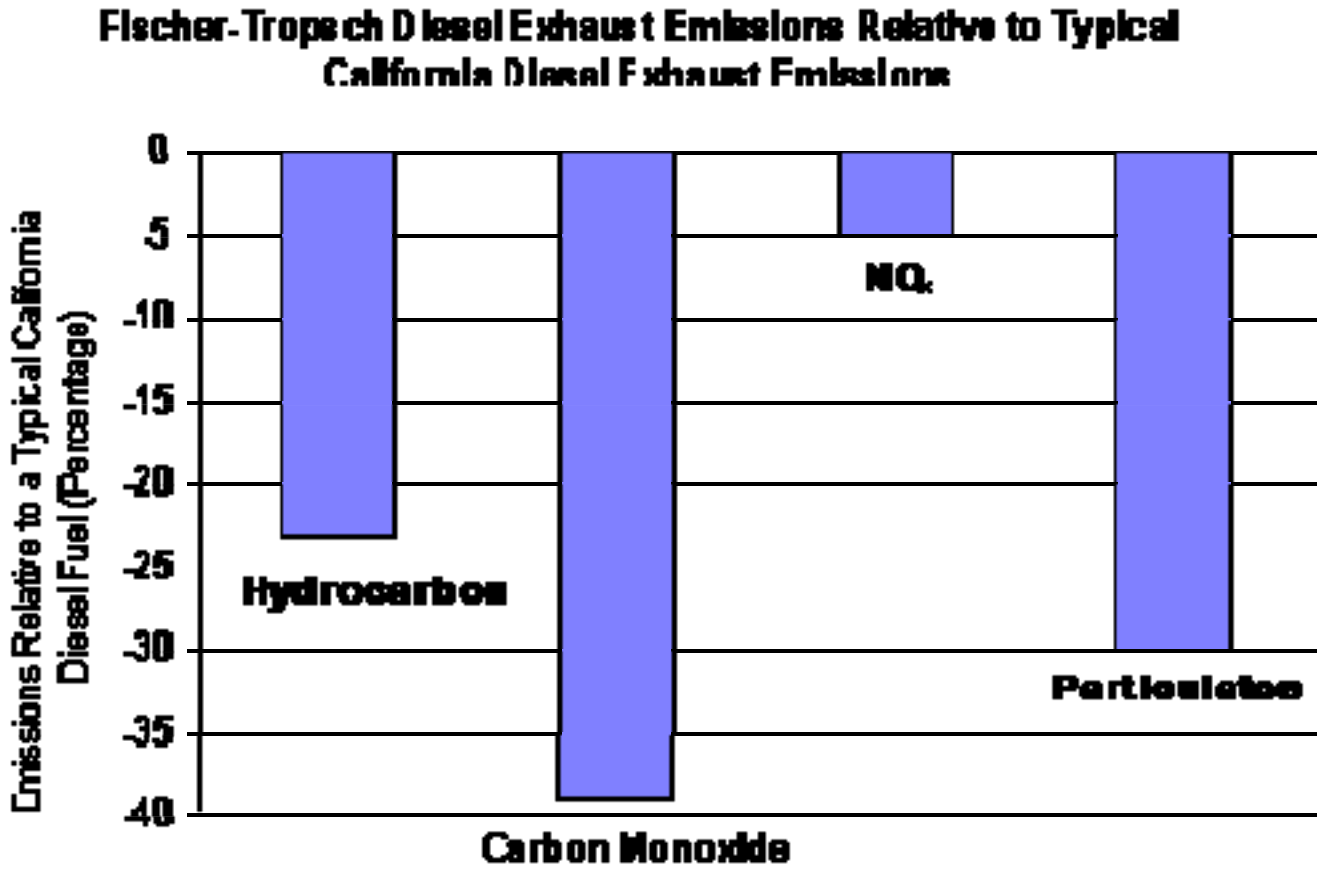
F-T Reduces Emissions

- **F-T Diesel Uniquely Cuts Key Emissions: EPA Study**
  - **"A joint industry/U.S. EPA heavy duty engine work group project found that Fischer-Tropsch diesel fuel uniquely produces a major improvement in exhaust emissions, compared to a group of conventional, crude-based diesels. F-T diesel produced a huge 36% drop in particulate matter (PM) emissions and a nearly 18% cut in nitrogen oxides (NO_x) compared to an ordinary U.S. highway diesel."**

World Fuels Today, 1/31/01

F-T Reduces Emissions

Preliminary testing of an unmodified diesel engine, fueled with neat synthetic diesel fuel, shows the following emission reductions compared to typical California diesel:[1]



1/Southwest Research Institute, AIChe, Emissions Performance of Fischer-Tropsch Diesel Fuels, March 1997.
Document Date: July 5, 2000

Energy Policy Act 2005 (HR 6)
Fischer-Tropsch Related

- **Title IV Coal:**
  Section 417: F-T fuels from Illinois coal
  to carry out program to evaluate technical and economic feasibility of advanced technologies to produce F-T fuels and other fuels from Illinois coal
  - includes technology identification and R&D
  $85MM over 4 years

- **Title IV Coal:**
  Sub-title C – Coal and Related Programs Section 421
  Amends Energy Policy Act of 1992 to Include Title XXXI – Clean Air Coal Program
  - Program of financial assistance for the production of clean coal-based power production – includes coproduction of fuels

- **Section 1703:**
  - loan guarantees for new technologies (taconite/western coals)
  - Funds awarded under CCPI may be used to finance the cost of obtaining a loan guarantee

Related Legislative Action

- **Energy Policy Act 2005**
  - Section 369 – Oil Shale, Tar Sands, and other Strategic Unconventional Fuels - Amends section 2398 (DOD)
  - Secretary of Defense shall develop a strategy to use fuels from domestic coal, oil shale and tar sands
  - Secretary may enter into 1 or more contracts to procure covered fuels for 1 or more requirement (with consultation of DOE)
  - Secretary may carry out assessment of current or potential locations in the U.S. for the supply of covered fuels
- **SAFETEA-LU**
  - Section 11113 – Volumetric Excise Tax Credit for Alternative Fuels
  - Provides $0.50 per gallon credit for Fischer-Tropsch Liquids produced from coal
  - This provision will terminate on September 30, 2009

Potential Deployment Scenario

- Sixty (60) plants by 2030 (2.4/year) produce 2 MMBPD and
  30 GW of power
- Compare to EIA forecast of 50 GW needed by 2020 (3.3/year)
- Capital cost $136 Billion over 25 years ($5.4 B/Year)
- Thirty-two percent additional coal required
- Oil import bill now is $240B (11 Million barrels/day = 4 billion barrels/year @ $60/barrel)

Benefits

- **Establish domestic industry (jobs)**
- **Enhance energy security**
  - liquid fuel production from domestic resource
- **Enable capture and storage of CO_2**
- **Reduce vehicle emissions**
- **Produce electric power as a by-product**

Conclusions

- It will be necessary in the future to develop alternatives to conventional petroleum when world demand outstrips supply; F-T fuels could be used as petroleum alternatives
- F-T fuels are ultra clean liquid fuels and would use existing transportation infrastructure.
- Cost of production of clean liquid fuels from coal in non-sequestration polygeneration plants is estimated to be about $35/BBL COE . From sequestered plants, CTL cost is estimated to range between $37 and $42/BBL COE depending on power value.
- Continued high world oil prices above $40/BBL would make CTL economically viable.
- Countries with large coal reserves and little domestic petroleum are candidates for using CTL to provide fuels to supplement conventional petroleum (China, US, Australia)
- Continued R&D and deployment of nth plants will improve the economics but incentives will likely be necessary for FOAK CTL plants to reduce risks for investors and thus accelerate commercial deployment.