Opportunities for the Early Production of Fischer-Tropsch (F-T) Fuels in the U.S. -- An Overview

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Outline of Presentation

• Background
• Fischer-Tropsch (F-T) Fuels from Natural Gas
  – DOE Ultra Clean Transportation Fuels Initiative (Conoco; ICRC/Syntroleum/Marathon Oil)
• F-T Fuels from Heavy Hydrocarbons
  – DOE Early Entrance Coproduction Plant Initiative (Texaco; WMPI)
• F-T Fuel Costs & Early Production Opportunities
• Conclusions
Aftertreatment Enabled By Low Sulfur Fuels

- Full Diesel Potential Cannot Be Reached Via Fuel Composition Changes
- NOx Presents a Major Technical Challenge

Ultra Low Sulfur Diesel Fuel versus Fischer-Tropsch Diesel

• Ultra Low Sulfur Diesel (ULSD) (15 ppm maximum sulfur)
  – To be Phased In Beginning in 2006
  – What Is In the Future??

• Fischer-Tropsch (F-T) Diesel
  – Attributes: Zero Sulfur and Zero Aromatics; Cetane Number > 70; Lower Heating Value; Lower Lubricity
  – Prudent Assumption: No Premium Over ULSD
  – Domestic Production of F-T Diesel – A Tough Challenge
Fischer-Tropsch (F-T) Fuel Production Technologies: Current Status

• Commercial F-T Fuel Plants In Operation
  – Natural Gas Feedstock: Shell (Malaysia), Mossgas (S. Africa)
  – Coal Feedstock: Sasol (S. Africa)
  – A 3-Step Process: Feedstock to Syngas (CO & H\textsubscript{2}), Syngas Conversion to F-T Crude, & Products Upgrading

• Advanced F-T Fuel Technologies Under Development
  – Natural Gas Feedstock: Active Industrial Interests
    • Monetize Stranded Gas Reserves
  – Heavy Hydrocarbons: Coproduction Strategy
    • Coproduce F-T Fuels with Electricity, Chemicals, Steam, ..
    • DOE-Industry Partnerships
Hurdles for Commercial Fischer-Tropsch (F-T) Fuels Production – A Partial List

• High Capital Costs
  – Continued R&D On Syngas (CO & H\textsubscript{2}) Production**

• Operating Complexity
  – Commercial-Scale Demonstration of Integrated Sub-Systems**

• Market Risks
  – Oil Price (Absolute & Volatility)
  – Customer Acceptance: Fleet Operational & Maintenance Data Base with F-T Fuels**

• Environmental Issues
  – Greenhouse Gases**

** DOE Supported R&D Activities
F-T Fuels from **Natural Gas**
-- New Commercial Demo Plants in U.S.

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Capacity</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conoco</td>
<td>Ponca City, OK (Next to Refinery)</td>
<td>400 b/d (F-T Fuels)</td>
<td>Startup 2003</td>
</tr>
<tr>
<td>Syntroleum</td>
<td>Tulsa, OK (Stand Alone)</td>
<td>70 b/d (F-T Fuels)</td>
<td>Startup 2003</td>
</tr>
<tr>
<td>BP</td>
<td>Nikiski, AK (Close to Refinery)</td>
<td>300 b/d</td>
<td>Startup 2002</td>
</tr>
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</table>
Conoco Gas-to-Liquids (GTL) Technology–Natural Gas Feedstock

• 400 b/d Commercial Demo Plant *(Self-Funded)*
  – Under Construction & Startup Scheduled for 2003
  – 3-Year Operation In F-T Mode Planned
  – Product Marketing Director Appointed
  – Participation In Clean Cities Program Under Consideration
    • Operational & Maintenance Data Base

• Commercial Size GTL Plants
  – Stranded Gas Reserves (Fields of 5 Trillion Cubic Feet (TCF) or Larger to Keep A 60,000 b/d Plant Full for 25 Years)
  – > 60,000 b/d
DOE-Conoco Cooperative Agreement: Evaluation of Ultra Clean Fuels from Natural Gas - Tasks 1 & 2

Subcontractor: Nexant, Inc.

• Task 1: Life-Cycle Assessment (LCA) – A Well to Wheel Analysis
  – Transportation & Power; Peer-Reviewed
  – Life Cycle Inventory & Life Cycle Impact Assessment
  – Feedstocks: Crude, Natural Gas, Corn, Biomass
  – Energy Use, Greenhouse Gases & Criteria Air Pollutants
• Task 2: Ultra Clean Fuels Market Assessment
  – F-T Fuels: Supply, Demand, & Pricing Issues in U.S. Relative to Competing Petroleum-Based & Other Alternative Clean Fuels; Feedstocks for Chemicals
  – Methanol: Infrastructure Issues
• Time Frame: Current, 2006, & 2015
DOE Cooperative Agreement with Conoco (Continued) – Task 3: Fuel, Engine, & Fuel Cell Testing (Jul 01-Nov 03)

Subcontractor: Pennsylvania State University

• Compression Ignition Engine Studies
  – Members: Cummins; Johnson-Matthey
  – Participant: Engelhard
  – Cummins ISB MY2000, 5.9L, 215/235 hp, Turbodiesel
    – Emission Monitoring: PM, NOx, HC, CO
    – Aftertreatment: CRT/NOx Adsorber; DPF/Urea-SCR
  – Fuel Formulation Effects :
    – Petroleum Diesel, Conoco F-T Diesel & Oxygenate (Biodiesel)
• PEM Fuel Cell Testing
  – Compare Indirect & Direct Methanol Fuel Cell Systems
  – Methanol Reformer Development
  – Transportation & Electric Power Applications
Syntroleum Gas-to-Liquids (GTL) Technology Development

Commercial Demo Plant
- 70 b/d Plant Erected in ARCO Refinery in Washington State & Operated from April 1999 to July 2000
- Produced F-T Synthetic Crude (C_{5+}) from Natural Gas Feedstock
- Mobile & Modular Units

Scaleup Beyond Commercial Demo Plant
- Small Footprint Plants (SFP) (1,000 – 5,000 b/d)
- Large Commercial Plants (5,000 – 180,000 b/d)
DOE-ICRC/Syntroleum/Marathon Oil Cooperative Agreement -- Partner & Participant Organizations

**Partners**
- Syntroleum
- UAF
- WVU
- MIT
- Daimler Chrysler
- A.D. Little
- Volkswagen
- Marathon
- Freightliner
- Mercedes
- Detroit Diesel

**Participants**
- Denali National Park
- WMATA
- AVL Powertrain
**DOE–ICRC/Syntroleum/Marathon Oil Cooperative Agreement: Gas-to-Liquids (GTL) Fuels Production & Demonstration**

**Prime Contractor:** Integrated Concepts & Research Corp. (ICRC)

- **Fuels Production Team:** Syntroleum**, & Marathon Oil
- **Engine Team:** ICRC**, AVL Powertrain*, MIT, DaimlerChrysler, & Volkswagen
  - F-T Fuels In Advanced Prototype Diesel Engines
- **Fleet Team:** ICRC Team Leader
  - Fleet Tests (WMATA*, Denali National Park*)
  - Emission Testing (West Virginia U.)
  - Small Footprint Plant (SFP) Feasibility & SFP Fuel Applications in Alaska (U. of Alaska at Fairbanks)
- **Market Team:** Consultant**, A.D. Little, & Syntroleum
  - Economic Analysis

**--------------------------**

**Team Leader**     **Participants**
DOE–ICRC/Syntroleum/Marathon Oil Cooperative Agreement (Continued) – 70 b/d F-T Fuel Small Footprint Plant (SFP)

- Natural Gas Feedstock
- Location: Port of Catoosa, Oklahoma (Near Tulsa)
- Use Equipment from Demo Plant in ARCO Refinery in WA
- Add F-T Syncrude Upgrading Step & Gas Turbine
- Under Construction & Startup/Operation In 2003
  - Operation Plan to Include F-T Jet Fuel Production
- Negotiations Underway Between Syntroleum & DOD for F-T Jet Fuel Production & Testing
- Unit On Standby After DOE Contract
DOE–ICRC/Syntroleum/Marathon Oil Cooperative Agreement (Continued) – F-T Fuel Fleet Tests

• Participants:
  – Washington (DC) Metro Area Transit Authority (WMATA)
  – Denali National Park, Alaska (Denali)

• Scope of Tests
  – Neat SFP F-T Diesel (Up to 24,000 gallons at Each Site)
    • Operational & Maintenance Data; Exhaust Emission Analysis
    • Benchmark: Low Sulfur Conventional Diesel
  – Test Period
    • Denali (May - September 2004)
    • WMATA (October 2003 to May 2004) – Different Seasons
  – WMATA: Single Engine Brand Fitted with PM Traps
  – Dynamometer Durability Tests to Precede Fleet Tests
F-T Fuels from Heavy Hydrocarbon Feedstocks

- Feedstocks: Coal, Petroleum Coke, & Biomass
- Technology Development Status
  - Coproduction Strategy (IGCC + F-T Synthesis)
    - IGCC (Integrated Gasification & Combined Cycle) to Produce Power, A Leading Clean Coal Power Technology
    - Coproduce Electricity, F-T Fuels, Steam, Chemicals & H₂
    - Higher Process Efficiency
    - Next Step: Commercial Demo of Integrated Sub-Systems
- DOE Early Entrance Coproduction Plant (EECP) Initiative
  - Feasibility Studies for Projects Adjacent to Existing Infrastructures, Carried Out In 3 Phases
  - Deliverable: Preliminary Engineering Design & Preliminary Project Financing Plan
Texaco-DOE Cooperative Agreement – Early Entrance Coproduction Plant (EECP)

- Subcontractors: Kellogg Brown & Root, General Electric, Praxair & Rentech
- Phase 1: Concept Definition & RD&T Planning (Completed)
  - Location: Adjacent to Motiva Refinery in Port Arthur, TX
  - Feedstock: Petroleum Coke @ 1235 Short Tons/Day
  - Finished Wax Case Has Most Favorable Financial Return
    - 457 b/d Wax, 125 b/d Diesel, 35 b/d Naphtha, 55 MW Power, Steam & Sulfur
    - 12% Internal Rate of Return: Zero Cost for Feedstock
- Phase 2: Research, Development & Testing (Underway)
  - Process R&D; Engine/Fuels Testing; Gas Turbine Tests
- Search for New Project Site Due to Chevron/Texaco Merger (Pending)
- Phase 3: Preliminary Engineering Design (Pending)
Waste Management Processors Inc. (WMPI)-DOE Cooperative Agreement – Early Entrance Coproduction Plant (EECP)

- Sub-Contractors: Texaco, Sasol Technology Ltd., & Nexant, Inc.
- **Phase 1: Project Feasibility Study (Underway)**
  - Location: Gilberton, PA (Adjacent to Coal Power Station)
  - Feedstock: Anthracite Coal Waste
  - Products Slate: 5,000 b/d F-T Fuels, 35 MW Electric Power, Steam & Sulfur
- **Phase 2: R&D/Testing (Pending)**
  - Feasibility Testing of Anthracite Coal Waste in Gasifier
- **Phase 3: Preliminary Engineering Design (Pending)**
## Unit Cost of Production ($/Barrel)

<table>
<thead>
<tr>
<th>Component</th>
<th>GTL</th>
<th>Refinery</th>
</tr>
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<tbody>
<tr>
<td>Natural Gas (@ $.50/MMBtu)</td>
<td>$4.00</td>
<td></td>
</tr>
<tr>
<td>Crude Oil (@ $17/Bbl)</td>
<td></td>
<td>$17.00</td>
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<tr>
<td>Operating Costs</td>
<td>3.00</td>
<td>2.50</td>
</tr>
<tr>
<td>Cash Costs</td>
<td>7.00</td>
<td>19.50</td>
</tr>
<tr>
<td>Capital Recovery, Taxes</td>
<td>12.00</td>
<td>6.50</td>
</tr>
<tr>
<td>Total Cost to Produce</td>
<td>$19.00</td>
<td>$26.00</td>
</tr>
</tbody>
</table>

Source: J. L. Rockwell (Conoco), CWC 2\textsuperscript{nd} Annual Global Summit, May 28-30, 2002, London, UK
Opportunities for Early Commercial Production of F-T Diesel in U.S.

- **Natural Gas Feedstock**: Dedicated F-T Fuels Plants
  - Stranded Gas in Alaska North Slope (Low Gas Price)
  - Sub-Quality Natural Gas: Syntroleum SFP Applications

- **Heavy Hydrocarbon Feedstock**: Coproduction Plants
  - Site-Specific Projects
    - High Sulfur Petroleum Coke with Zero or Negative Costs
    - Other Environmentally Disadvantageous Feedstocks
  - DOE Clean Coal Power Initiative (CCPI) Solicitation
    - 10 Year, $2 Billion Program (DOE Share)
      - Requires >50% Cost Sharing
    - Feedstock: >75% of Heating Value from Coal
    - Coproduction Mode Allowed
    - Round 1 Solicitation Underway
Opportunities for Early Commercial Production of F-T Diesel (Continued)

• Prospects of Early F-T Fuels Production Could Be Improved with Assistances
  – Encourage Early F-T Fuels Use
      – Wider Use of Alternative Fuels In Alternative Fuel Vehicle (AFV) Fleets
    • DOD Interests In Using F-T Fuels in Advanced Propulsion System (Joint Work between Air Force & DOE/NETL)
  – Financial Incentives To Nurture New Alternative Clean Fuel Technologies
    • Pennsylvania S.B. 650 Coal Waste Removal & Ultra Clean Fuels Tax Credit Enacted In 1999
      – Capped at $47 Million
Conclusions

• Successful Startup & Operation of the 3 Commercial Demo Plants Beginning In 2002 Could Mark the Beginning to Make Domestically Produced F-T Fuels Available for Commercial Applications.
• Planned Fleet Tests Should Yield An Extensive Operating & Maintenance Data Base for F-T Diesel Applications
• Results of EECP Feasibility Study Appears Encouraging with Project Sited Next to Refinery and Using High Sulfur Petroleum Coke as Feedstock.
• Early Domestic Production of F-T Fuels Could Be with Stranded Gas Reserves or in Site-Specific Projects In Coproduction Mode with Coal and/or Petroleum Coke as Feedstocks
• Prospects of Early Domestic F-T Fuels Production Could Be Improved with Assistances Including Wider Use of F-T Fuels in AFV fleets under EPAct, and Financial Incentives with Capped Limit.