Affordable, Low-Carbon Diesel Fuel from Domestic Coal and Biomass

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Coal and Biomass to Diesel Fuel

Overview

CBTL Presentation Outline

• Background & Context
  • Study Goals
  • Strategic Issues

• Methodology
  • Plant Configuration
  • Economic Assumptions
  • GHG Accounting

• Results
  • FT Diesel GHG Profile
  • Capital Costs
  • Effects of Carbon Pricing on Economics

• Summary
Coal and Biomass to Diesel Fuel

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- Summary

**Terminology**

- Coal to Liquids (CTL)
- Coal and Biomass to Liquids (CBTL)
- Biomass to Liquids (BTL)

CCS = Carbon Capture and Storage

ATR = Auto-Thermal Reformer
Coal and Biomass to Diesel Fuel

Study Goals…

Affordable, Low-Carbon Diesel Fuel from Domestic Coal and Biomass
Coal and Biomass to Diesel Fuel

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Affordable, Low-Carbon Diesel Fuel from Domestic Coal and Biomass

“Affordable”
Comparable in price to today’s fuels and projected future prices
Coal and Biomass to Diesel Fuel

**Study Goals**

Affordable, Low-Carbon Diesel Fuel from Domestic Coal and Biomass

- **“Affordable”**
  Comparable in price to today’s fuels and projected future prices

- **“Low-Carbon”**
  Having life-cycle GHG emissions similar to or below petroleum-derived diesel
Coal and Biomass to Diesel Fuel

Study Goals...

Affordable, Low-Carbon Diesel Fuel from Domestic Coal and Biomass

- **“Affordable”**
  Comparable in price to today’s fuels and projected future prices

- **“Low-Carbon”**
  Having life-cycle GHG emissions similar to or below petroleum-derived diesel

- **“Domestic Coal and Biomass”**
  Fuels are produced from domestically available feedstocks.
Coal and Biomass to Diesel Fuel

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“Affordable”
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Fuels are produced from domestically available feedstocks
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Fuels are produced from domestically available feedstocks

Economic Sustainability

Energy Supply Security

Climate Change

Economic Sustainability
Energy Strategy Complexity

**Energy Supply Security**
- 12 MMbpd of imports
- 66% of our refinery inputs

- Economic Sustainability
- Climate Change

NATIONAL ENERGY TECHNOLOGY LABORATORY
Energy Strategy Complexity

**Economic Sustainability**
- Oil is up 75% from Jan07
  + $326B sent off-shore in 2007
  + $360B already spent as of July
- Businesses hit hardest
  + Inelastic demand in diesel/jet
  + Refining capacity limitations
Energy Strategy Complexity

- Climate Change
  - Highest GHG emissions of any sector
  - No easy way to reduce emissions from existing infrastructure:
    + Small point sources
    + Dilute gas

Economic Sustainability

Energy Supply Security

Climate Change
Energy Strategy Complexity

Aiming for Balanced Solutions

- Economic Sustainability
- Energy Supply Security
- Climate Change
Methodology

- Plant Configurations
- Economic Terminology & Assumptions
- GHG Accounting
Coal and Biomass to Diesel Fuel

Plant Configurations

10 Plant Configurations
Coal to Liquids (CTL)
Coal and Biomass to Liquids (CBTL)
Biomass to Liquids (BTL)

$CCS = \text{Carbon Capture and Storage}$

$ATR = \text{Auto-Thermal Reformer}$

Configuration Notes
- 50,000 bpd maximum plant size
- Max Biomass Feed: 4,000 dry tons per day
  - Marginal land only: Food Crops Not Displaced
  - 30-50 mile collection radius
  - No soil/root carbon
- Fuels Production Maximized
  - Zero Excess Power Produced
  - Recycle Configuration

$CO_2$ Capture
- $CCS \rightarrow >90\% CO_2$ Capture
- $CCS+ATR \rightarrow >95\% CO_2$ Capture
Economic Methodology

Terminology & Assumptions

• **Required Selling Price (RSP)**
  • Price diesel fuel product must be sold at to cover costs
    • Operating Costs
    • Debt Service
    • Repay Investors (20% IRROE)
Economic Methodology

Terminology & Assumptions

• **Required Selling Price (RSP)**
  - Price diesel fuel product must be sold at to cover costs
    - Operating Costs
    - Debt Service
    - Repay Investors (20% IRROE)

• **Crude Oil Equivalent Price (COE)**
  - Diesel market price defined by petroleum-derived diesel, and therefore crude oil
    - Historically, the price ratio of ultra-low sulfur petroleum diesel (ULSD) is sold for 125% the price of crude oil

• **By-product Sales**
  - Naphtha by-product market price is 77% of diesel price
Financing Scenarios for xTL Plants

- **Coal-based projects are unlikely to be financed in the near-term**
  - Carbon regulatory uncertainty
  - Oil price uncertainty
  - Technical uncertainty

- **3rd or 4th of a kind plant still considered risky**
  - Require “High Risk” Financing
  - Fuels market has high level of uncertainty
  - Carbon regulation has passed, removing regulatory risk

- **Government incentives can significant mitigate risks**
  - Extend Debt Term and reduce interest rates
  - Applicable incentives already in place in EPACT 2005 and CCPI

<table>
<thead>
<tr>
<th></th>
<th>Near-Term: 100% Equity</th>
<th>Mid-Term: No Incentives</th>
<th>Mid-Term: Gov’t Incentives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt/Equity Ratio</td>
<td>0</td>
<td>50/50</td>
<td>60/40</td>
</tr>
<tr>
<td>Debt Term¹</td>
<td>n/a</td>
<td>15 years</td>
<td>25 years</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>n/a</td>
<td>9.5%</td>
<td>7.5%</td>
</tr>
<tr>
<td>IRROE</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

¹ Economic life of the plant is assumed to be 30 years.
² This is the NETL reference case.
Climate Change

Petroleum-Derived Diesel GHG Emissions

Vehicle Operation 83%

Crude Oil Extraction & Transportation 7%

Refining 9%

Transportation & Distribution 1%

Source: GREET 1.8b set at Year 2005
Climate Change

Effects of GHG Regulation on Economics

- **Hypothetical Carbon Trading Scheme**
  - Petroleum-derived diesel is used as a reference case for emissions
  - FT diesel price is affected by life-cycle emissions of the fuel
    - Carbon credit given for diesel fuel with reduced emissions
      - Reduces RSP
    - Carbon debit charged if emissions are greater than petroleum-diesel
      - Increases RSP
  - NOTE: Price of petroleum-derived products are not affected (baseline)

- **Low-Carbon Fuel Standard (LCFS)**
Results
Emissions of CBTL Plants Compared to Petroleum Diesel

Source for Petroleum-derived diesel: GREET 1.8b, 2005 base year
Emissions of CBTL Plants Compared to Petroleum Diesel

Adding CCS brings CTL 2-10% below Petroleum diesel

Source for Petroleum-derived diesel: GREET 1.8b, 2005 base year
Emissions of CBTL Plants Compared to Petroleum Diesel

Adding up to 30 wt% biomass brings CBTL 74% below petroleum diesel

Source for Petroleum-derived diesel: GREET 1.8b, 2005 base year
Emissions of CBTL Plants Compared to Petroleum Diesel

BTL with CCS is 300+% below petroleum diesel

Source for Petroleum-derived diesel: GREET 1.8b, 2005 base year
Required Selling Price for Diesel Product

Credit/Debit for Life-Cycle GHG Emissions Below/Above Petroleum Baseline, Jan-08 $/metric ton CO2-equivalent

- 100% SG, no CCS, 5k bpd, -110%
- 100% Coal, no CCS, 50k bpd, +152%

D/E = 60/40; Int. = 7.5%; Term = 25 yrs.; IRROE = 20%

CTL and BTL without CCS
When the GHG emission value is zero, BTL isn’t feasible until oil is well over $200/bbl.

CTL is feasible when oil exceeds $84/bbl.

D/E=60/40; Int.=7.5%; Term=25 yrs.; IRROE=20%
Adding CCS and an ATR to the BTL case reduces life-cycle GHG emissions to a level 364% below the petroleum baseline. But it is not economically preferred until the GHG emission value exceeds $95/tonne.
When the option of CTL+CCS is added, it becomes economically preferred when the GHG emission value is between $5 and $135/tonne.
Adding CCS increases the RSP by only $2/bbl (to $84/bbl) while reducing life-cycle GHG emissions to a level that is 2% less than the petroleum baseline.
Adding an ATR reduces GHG emissions to a level 10% below the petroleum baseline, but is not an economically preferred option.
Required Selling Price for Diesel Product

CBTL+CCS:
- 30 wt%
- 15 wt%

D/E=60/40; Int.=7.5%;
Term=25 yrs.;
IRROE=20%
15 wt% reduces life-cycle GHG emissions to a level 31% below the petroleum baseline and is feasible when oil exceeds $93/bbl.
The 15wt% CBTL+CCS option is economically preferred when the GHG emission value is between $100 and $140/tonne.
**Required Selling Price for Diesel Product**

- **100% SG, CCS+ATR, 5k bpd, -364%**
- **100% Coal, no CCS, 50k bpd, +152%**
- **100% Coal, CCS, 50k bpd, -2%**
- **15 wt% SG, CCS, 50k bpd, -31%**
- **30 wt% SG, CCS, 30k bpd, -61%**

30 wt% reduces life-cycle GHG emissions to a level 61% below the petroleum baseline but is not an economically preferred option.
If a low-carbon fuel standard mandated a 20% life-cycle GHG emission reduction, all the coal-only options would be eliminated.
Summary of Economic Analysis

- CTL without CCS is the economically preferred alternative when GHG emission values are less than $5/metric ton of CO₂-equiv.

- CTL is economically feasible over this range of GHG emission values when crude oil prices are $84/bbl or higher.

- Adding CCS to CTL is economically justified when the GHG emission value exceeds $5/metric ton CO₂ equiv. and produces diesel fuel with life-cycle GHG emissions that are 2% below the petroleum baseline.

- Adding CCS to CTL is very inexpensive, increasing the COE-RSP by only $2/bbl
Summary of Economic Analysis

• Absent a low-carbon fuel standard, CBTL is not an economically preferred option unless GHG emission values exceed $100/metric ton of CO₂-equiv.

• Under a 20% LCFS, the coal-only cases do not qualify and CBTL configurations would be economically preferred when GHG emission values range between $0 and $140/metric ton of CO₂-equiv.

• The 15wt% CBTL plant has life-cycle GHG emissions that are 31% below the petroleum baseline and is economically feasible when oil prices are $93/bbl or higher, even if the GHG emission value is zero.

• BTL plants are not economically preferred unless GHG emission values are extraordinarily high (above $140/metric ton of CO₂-equiv).
Effect of Financing Scenarios on Diesel RSP (when GHG Emission Value is Zero)

- Today - 100% Equity
- Mid-Term - No Gov't Incentive
- Mid-Term - Loan Guarantee (NETL Ref.)

Mid-term scenarios assume a carbon regulation has been passed. All scenarios assume that two or three CTL/CBTL plants have been demonstrated in the U.S.
Effect of Financing Scenarios on Jet Fuel RSP
(when CO₂ Allowance Price is Zero)

A “moderate” incentive, such as a loan guarantee, could make the use of CCS and biomass economically preferable to CTL without CCS (even when CO₂ allowances are valued at zero).
The Path Forward
Future Publications and Acknowledgements

Publications
Affordable, Low-Carbon Diesel Fuel from Domestic Coal and Biomass
Estimated Publication Date: October 2008

Petroleum Baseline Life Cycle GHG Analysis
Estimated Publication Date: October 2008

Noblis
– David Gray
– Charles White

Princeton Environmental Institute
– Dr. Robert Williams
– Eric Larson
– Thomas Kreutz
Questions?
Additional Information
Total As-Spent Capital Cost
(includes escalation & interest during construction)
Distribution of Total Overnight Capital Costs

15 wt% CBTL+CCS, 50k bpd

- Gasification Island: 32%
- CO₂ Removal, Comp., Transport, Seq. & Monitoring: 5%
- FT Synthesis: 11%
- Contingencies: 20%
- Engineering & Construction Mgmt.: 6%
- Balance of Plant: 9%
- Inventory, Pre-Production & Owner's Costs: 6%
- Fuel Handling, Prep & Feed: 11%

TOTAL: 100%
### Basis of Scenario 2A Finance Structure

<table>
<thead>
<tr>
<th>Capital, % Debt</th>
<th>Industry-Based Recommendation for Scenario 2 (1)</th>
<th>Likely Range of Loan Guarantee Impacts (2)</th>
<th>Assumptions for Scenario 2A</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>up to 30 point increase</td>
<td>60 (10 point increase)</td>
<td></td>
<td>The percentage of capital financed with debt was limited to 60% such that the DSCR was above 2.0 given the debt interest rate, debt term and IRROE assumed below. DSCR values above 1.75 will likely be required to secure debt financing [1].</td>
</tr>
<tr>
<td>Debt Interest Rate, %</td>
<td>9.5 (LIBOR+6)</td>
<td>1 to 2.5 point decrease</td>
<td>7.5 (2 point decrease; LIBOR+4)</td>
<td>The interest rate on the guaranteed loans would likely be well below LIBOR+4, perhaps equal to the rate of a Treasury Bond. However, the competitive selection process may result in awards of federal loan guarantees that cover only a portion of the project debt. Consequently, the rate assumed here can be interpreted as the weighted average of the guaranteed and unguaranteed rates.</td>
</tr>
<tr>
<td>Debt Term, years</td>
<td>15 up to 15 year increase</td>
<td>25 (10 year increase)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required IRROE (over 30 years), %</td>
<td>20 no impact</td>
<td>20 (no change)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- The 12-month LIBOR is assumed to be 3.5%.
- The debt service coverage ratio (DSCR) is the ratio of the operating profit to the cost of debt service (principal plus interest).
- (1) Based on a 2008 NETL report that recommends finance structures for fossil energy projects [1].
- (2) Based on 2007 NETL report that assesses the impact of government incentives on the economics of a Fischer-Tropsch plant [2].
Climate Change
Petroleum-Derived Diesel GHG Emissions

- Raw Material Acquisition (coal and/or non-food biomass)
- Transport to the Energy Conversion Facility
- Energy Conversion Facility (with carbon capture and transport)
- Transport, Storage, and Dispensing
- End Use

Study Boundary
Life-Cycle GHG Emissions Equation

Total Cradle-to-Gate GHG Emissions for Producing Diesel, Naphtha, and Electricity (Raw Material Acquisition thru the exit gate of the energy conversion facility)

(-) Carbon Content (converted to CO₂) of the Biomass Feedstock Utilized by the Energy Conversion Facility (applicable to CBTL facilities only)

(-) Naphtha Cradle-to-Gate GHG Co-product Displacement Value per Million Btu of Naphtha Produced

(-) Electricity Cradle-to-Gate GHG Co-product Displacement Value per Million Btu of Electricity Produced

(+) GHG Emissions from Transportation & Distribution of Diesel Fuel to the End User

(+) GHG Emissions from Combustion of the Diesel Fuel in the End Users Vehicle

Total Life-Cycle GHG Emissions for FT diesel Produced from a CTL or CBTL Facility
Comparison of Diesel Fuel Greenhouse Gas Profiles from Various Studies

- McCann, O&G Journal (1999), Venezuela Very Heavy Crude
- McCann, O&G Journal (1999), Venezuela Heavy Crude
- McCann, O&G Journal (1999), Saudia Light Crude
- California LCFS (2007) - modified GREET Model
- McCann, O&G Journal (1999), Canadian Light Crude
- GM Study WTT (2001)
- U.C. Davis, LEM (2003), Year 2015
- GREET Ver. 1.8b (2008), Year 2010
- EPA, OTAQ (2006) Average Value
- GREET Ver. 1.8b (2008), Year 2005
- NREL Biodiesel Study (1998)

Life Cycle GHG Contribution (g-CO$_2$E/mmBtu of Fuel Dispensed)

...to Fuel Dispensing (vehicle tank).

From Extraction (oil well)...

- 5,000
- 10,000
- 15,000
- 20,000
- 25,000
- 30,000
- 35,000
- 40,000
Life-Cycle GHG Emissions for 15wt% CBTL with CCS

Net to Atmosphere + 2,015 t/d - 9425 BPD S

8,091 t/d In

9,425 BPD Synthetic Diesel
20,575 BPD Synthetic Naphtha

8,091 t/d Out

81 t/d

4363 t/d

976 tcd

3240 tcd

2264 tcd

0 tcd

Credit for Upstream GHG Emissions for Producing Naphtha from Petroleum

Electric Grid Credit

Transportation of Synthetic Diesel Fuel

Carbon Storage

Coal Mining and Transportation

Biomass Cultivation and Transportation

Soil/Root Carbon
Required Selling Price for Diesel Product

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<tr>
<th>Description</th>
<th>Equivalent Crude Oil Price, Jan-08 $/bbl</th>
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<td>120</td>
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<td>95</td>
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<td>90</td>
</tr>
<tr>
<td>15 wt% SG, CCS+ATR, 50k bpd, -40%</td>
<td>88</td>
</tr>
<tr>
<td>30 wt% SG, CCS, 30k bpd, -61%</td>
<td>85</td>
</tr>
<tr>
<td>30 wt% SG, CCS+ATR, 30k bpd, -74%</td>
<td>82</td>
</tr>
<tr>
<td>9 wt% SG, CCS, 50k bpd, -20%</td>
<td>79</td>
</tr>
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</table>

Credit/Debit for Life-Cycle GHG Emissions Below/Above Petroleum Baseline, Jan-08 $/metric ton CO2-equivalent

D/E=60/40; Int. =7.5%; Term=25 yrs.; IRROE=20%