MITIGATING CO$_2$ PRODUCTION IN COAL-TO-LIQUIDS PROCESSES

Presented by Robert Walty
C2O Corporation
INTRODUCTION

• **Coal-To-Liquids Definition**
  – Process of converting all or part of the raw coal to liquid alternative fuels with petroleum fuel properties.
  – Requires thermo-chemical treatment to accomplish the conversion.
  – Results in CO₂ production equivalent to the net fossil-fuel energy required to drive the processes.

• **Environmental Challenges**
  – Compliance with current local, state and federal regulations.
  – Technology to capture and convert all pollutants to products.
  – Mitigate the life-cycle CO₂ footprint of synthetic fuel to less than that of petroleum fuels.
According to BP, Transport comprises 21% of CO2 emissions world wide.

2.5B PEOPLE
5X THE VEHICLE OWNERSHIP
IN <30 YEARS!
Petroleum Refining is the Key Energy Conversion Step for Gasoline and Diesel

- **Petroleum recovery (97.5%)**
  - Petroleum transportation and storage

- **Natural gas**
  - Methanol
  - MTBE

- **Corn**
  - Ethanol

**Petroleum refining to gasoline (84.5-86%) and diesel (87%)**

- Petroleum transportation and storage

**Gasoline and diesel at refueling station**

*Note: Based on GREET model, regarded by SAE as the gold standard of well-to-wheel's model.*

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Michael Wang
Center for Transportation Research
Argonne National Laboratory

The Energy Modeling Forum on Climate Change
Impacts and Integrated Assessment

Stevens, ID. August 21, 2008

8/10/2009

R. Waltz - C2O Corporation
UNITED STATES ENERGY SECURITY AT RISK
DRIVEN BY US AND FOREIGN DEMAND WITH DECREASING OIL RESOURCES

INELASTIC DEMAND
WITH DECLINING US PRODUCTION

THE WORLD'S OIL PRODUCTION IS IN DECLINE

Figure 17: Consumption, Production and Import Trends for Petroleum (1950-2007).

Source: Energy Information Administration, Annual Energy Review 2007 Table 5.1 (June 2008)

1 Petroleum products supplied is used as an approximation for consumption.
2 Crude oil and natural gas plant liquids production.

Source: Energy Information Administration, June 2009 Import Highlights: August 13, 2008

COMPOUNDED BY DWINDLING GLOBAL SUPPLY

USA IMPORTS

OGI, 9 Feb2004 (Jan-Nov 2003)
REDUCING AMERICA’S DEPENDENCE ON IMPORTS

Figure EX-5. Mitigation Impacts if Initiated in 2006

PRODUCTS MUST CONFORM TO PETROLEUM STANDARDS
LONG-TERM ECONOMIC VIABILITY
DRIVEN BY THE VALUE OF OIL RELATIVE TO COAL

Source: US DOE Annual Energy Outlook 2006

Coal is Projected to Have a Significantly Lower Cost Than Oil Over the Next 25-30 Years—Btu Arbitrage
SUMMARY OF COAL-TO-LIQUIDS TECHNOLOGIES

• DIRECT CONVERSION
  – Finely ground coal is mixed with solvent and reacted in the presence of hydrogen and catalyst to produce synthetic crude oil.
  – Requires moderate temperature and high pressure.
  – Processing results in high process energy and water consumption.
  – Equipment is high in foreign content.

• INDIRECT CONVERSION
  – Finely ground coal is gassified to produce syngas which is reformed over a catalyst to produce synthetic diesel and other products.
  – Requires moderate pressures at very high temperatures, (>2,800 deg. F).
  – Processing results in high process energy and water consumption.
  – Equipment is high in foreign content incorporating expensive ceramic lined hot gas handling components and catalysts.

• PARTIAL CONVERSION
  – Corse ground coal is heated producing coal char and condensable gasses which are converted into synthetic crude oil by hydrogenation over a catalyst.
  – Requires moderate temperatures, pressures.
  – Processing results in moderate energy consumption and produces water.
  – Equipment is simple steel and stainless steel construction with high US content.
WORLD’S LARGEST DIRECT CONVERSION PROJECT

WVU/NRCCE Supporting Shenhua Project

- Shenhua (China’s largest coal Co.) building 100,000 bpd plant
  - 20,000 bpd production starts this year
  - Construction 99.5% complete
  - Direct liquefaction technology

- $1.5 million study of plant’s economic and environmental effects underway
- Carbon sequestration to be included
- Collaborators:
  - USA: DOE/FE and WVU/NRCCE
  - China: Shenhua Group and National Development Reform Commission

Mr. Ren (Shenhua), Drs. Fletcher and Sun (WVU) at Shenhua Liquefaction Pilot Plant
INDIRECT CONVERSION IS VERY ENERGY INTENSIVE

1. Coal mining and cleaning (99.3%)
2. Coal transportation
3. Coal gasification
4. Syngas synthesis (42-52%?)
5. FT diesel transportation and storage
6. FT diesel at refueling station

**Thermochemical Process**

- Feed Coal
- Gasification (>2,800°F)
- Gas Cleanup
- Fuel Synthesis
- Power Plant/Gas Turbine
- FTD or DME
- FTG, FTN
- Electricity

**NOTE:** FROM NATURAL GAS, F-T DIESEL IS 61% EFFICIENT

Michael Wang
Center for Transportation Research
Argonne National Laboratory
The Energy Modeling Forum on Climate Change Impacts and Integrated Assessment
Stevens, CO, August 3, 2009
SUCCESSFULLY TESTED IN SEVEN POWER PLANTS
+7% EFFICIENCY, -70% SULFUR, (-85% Mercury)
NOTE: POWER PRODUCTION IS DECOUPLED FROM FUEL PRODUCTION

ENCOAL PLANT OPERATED 1992 - 1997

CLEAN COAL FUEL

Truck & semi-trailer

83,000 TONS PRODUCED

COAL-OIL

4.9MM GAL. PRODUCED

FRESH WATER

HYDROTREATED TO SYNTHETIC CRUDE OIL

Demonstration plant - 1,000 tons of feed coal per day
PARTIAL CONVERSION PROCESS

CLEAN WATER TO EXPORT
(100% of Moisture)

PROCESS FUEL GAS
(INTERNAL USE)
(~7 w%)

SYNTHETIC CRUDE OIL
(~15 w%)

SULFUR

ELECTRIC POWER
(INTERNAL USE)

CLEAN COAL FUEL
(Balance)

SECTION - 700 WATER TREATMENT

SECTION - 800 PROCESS GAS TREATMENT

SECTION - 100 PYROLYSIS

SECTION - 200 OIL RECOVERY

SECTION - 300 HYDROTREATER

SECTION - 400 GASIFICATION

SECTION - 500 HYDROGEN PRODUCTION

SECTION - 900 COGENERATION

COAL

1,000 F.
EFFICIENCY DRIVES CO$_2$ EMISSIONS AND CAPITAL

COAL WITH 30% MOISTURE

COAL WITH 10% MOISTURE

ALTERNATES vs PARTIAL CONVERSION

ALTERNATES vs PARTIAL CONVERSION

8/10/2009  R. Walty - C2O Corporation
Carbon Emissions Could Be a Major Concern for Coal to FT Diesel

- If coal-to-liquid (CTL) plant has an energy efficiency of 52%, CTL WTW CO$_2$ emissions will be two times as much as those of petroleum diesel.
- With carbon capture and storage, CTL WTW CO$_2$ emissions will be about the same as those of petroleum diesel.
- If CTL plant has an energy efficiency of 42%, CTL WTW CO$_2$ emissions will be 2.3 times as much as those of petroleum diesel.
- Integrated design of CTL plants to produce fuels and power will help improve plant efficiency.

NOTE: CO$_2$ EMISSIONS ARE INVERSELY PROPORTIONAL TO EFFICIENCY AND ARE NOW THE MAJOR CONCERN.
THE CO₂ CHALLENGE TO F-T SYNTHETIC FUELS

Secretary of Air Force Goals *

- By 2011, certify entire AF fleet to use 50/50 synfuel blends
- By 2016, acquire 50% of CONUS aviation fuels from domestically produced synthetic fuel blends

* EPACT 2007 says fuel must have equal or lower carbon footprint than petroleum fuels

RESULT: 25,000 BPD F-T DEMONSTRATION IN MONTANA WAS CANCELED IN 2008

*CTL MUST BE CO₂ NEUTRAL OR NEGATIVE!
MEETING THE “0” CO₂ ALTERNATIVE FUEL CHALLENGE

DIRECT & INDIRECT CONVERSION (HTI & SASOL)

PARTIAL CONVERSION

PETROLEUM
CO₂ STRATEGY #1- CAPTURE AND SEQUESTER

CURRENT FLEET

HYDROGEN PRODUCTION FOR CTL & OIL PROCESSING

Figure SPM.3. Schematic representation of capture systems. Fuels and products are indicated for oxyfuel combustion, pre-combustion (including hydrogen and fertilizer production), post-combustion and industrial sources of CO₂ (including natural gas processing facilities and steel and cement production) (based on Figure 3.1) (Courtesy CO2CRC).
CO$_2$ CAPTURE AND SEQUESTRATION

MITIGATING CO$_2$ IS ESSENTIAL BUT SEQUESTERING CO$_2$ IS A DIFFICULT AND EXPENSIVE PROPOSITION.

2x THE CAPITAL
-30% EFFICIENCY
150% ELECTRICITY COST

MIT THE FUTURE OF COAL 2007
Confirmed by AEP & NETL
“CLOSED LOOP” CO₂ MITIGATION W/ BIOMASS (TERRESTRIAL OR AQUATIC)

- Plants absorb CO₂ and biomass can fuel processes.
- Waste heat is available for drying the biomass.
- Biomass can be co-fired with other solid fuels like coal.
- Biomass can yield additional oil products.
- Land can be used which is not suitable for food crops.
<table>
<thead>
<tr>
<th>PLANT DESIGN</th>
<th>REF 01</th>
<th>SASOL</th>
<th>HTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Coal (t/day)</td>
<td>10,000</td>
<td>23,400</td>
<td>9,450</td>
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<tr>
<td>bbls/day</td>
<td>7,600</td>
<td>80,000</td>
<td>20,000</td>
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<table>
<thead>
<tr>
<th>CTL PROCESS</th>
<th>PARTIAL</th>
<th>INDIRECT</th>
<th>DIRECT</th>
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<tbody>
<tr>
<td>Oil Product</td>
<td>15%</td>
<td>29%</td>
<td>32%</td>
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<tr>
<td>Metallurgical Coal Product</td>
<td>60.0%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Water (% of Coal)</td>
<td>10.0%</td>
<td>10.0%</td>
<td>10.0%</td>
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<tr>
<td>Ash (% of Coal)</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Energy (% of Coal)</td>
<td>10%</td>
<td>56%</td>
<td>53%</td>
</tr>
<tr>
<td>Water (gal/bbl oil)</td>
<td>29</td>
<td>-294</td>
<td>-815</td>
</tr>
<tr>
<td>Relative % CO₂</td>
<td>19%</td>
<td>100%</td>
<td>94%</td>
</tr>
<tr>
<td>CO₂ (tons / ton feed coal)</td>
<td>0.26</td>
<td>1.39</td>
<td>1.32</td>
</tr>
<tr>
<td>CO₂ (tons / bbl oil)</td>
<td>0.29</td>
<td>0.56</td>
<td>0.58</td>
</tr>
<tr>
<td>Nul CO₂ w/Biomass (t/bbl)</td>
<td>0.22</td>
<td>0.41</td>
<td>0.43</td>
</tr>
<tr>
<td>Biomass (t/d) @10k bbl/d</td>
<td>2,153</td>
<td>4,134</td>
<td>4,318</td>
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<tr>
<td>CAPX ($/bbl-year)¹</td>
<td>$100</td>
<td>$208</td>
<td>$208</td>
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<tr>
<td>CAPX ($/rev $-day)</td>
<td>$530</td>
<td>$1,000</td>
<td>$1,000</td>
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(1) CCI CAPX allocated based on revenue split between M-Coal & Oil
FOREST BIOMASS PROCESS FUEL EXAMPLE

Kentucky State Energy Plan, 2008 for Forest Products or Miscanthus

Table 3: Renewable Electricity Generation Targets to 2025

<table>
<thead>
<tr>
<th>Renewable Resource</th>
<th>Existing¹</th>
<th>2012</th>
<th>2018</th>
<th>2025</th>
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<tbody>
<tr>
<td>Total Generation</td>
<td>3,052</td>
<td>4,509</td>
<td>6,694</td>
<td>9,244</td>
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<tr>
<td>Wind Energy</td>
<td>0</td>
<td>69</td>
<td>172</td>
<td>293</td>
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<tr>
<td>LFG / Biogas</td>
<td>88</td>
<td>191</td>
<td>347</td>
<td>528</td>
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<tr>
<td>Solar PV</td>
<td>0</td>
<td>272</td>
<td>679</td>
<td>1,154</td>
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<tr>
<td>Hydropower</td>
<td>2,592</td>
<td>2,708</td>
<td>2,883</td>
<td>3,087</td>
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<tr>
<td>Forest Biomass</td>
<td>372</td>
<td>1,268</td>
<td>2,613</td>
<td>4,182</td>
</tr>
</tbody>
</table>

Equiv. tons Biomass / day 739 2,516 5,185 8,298

At an oil production rate in bbls/day = 7,600 79,800 171,000

F-T diesel / Direct t/day to “0” CO₂ = 3,116 32,718 70,110

Partial Conversion t/day to “0” CO₂ = 1,672 17,556 37,620

( BASED ON COAL DRY WEIGHT )
CO$_2$ RECYCLING RETROFIT WITH ALGAE BIOMASS

Figure SPM.3. Schematic representation of capture systems. Fuels and products are indicated for oxyfuel combustion, pre-combustion (including hydrogen and fertilizer production), post-combustion and industrial sources of CO$_2$ (including natural gas processing facilities and steel and cement production) (based on Figure 3.1) (Courtesy CO2CRC).

Eighth Session of IPCC Working Group III
CLEAN ENERGY PLANT CONCEPT
SUMMARY

• Coal-to-liquids process offers opportunities for domestic fuel supply and energy security.
• While these technologies are technically mature they face significant environmental challenges, especially from CO$_2$ emissions.
• Advances in bio-energy production can significantly mitigate the CO$_2$ issues when integrated with the right CTL processes.
• Work is needed to integrate these processes and scale them up for industrial application.
THANK YOU!