The U.S. Coal to Clean Transportation Fuels Options:
A Game Theory Assessment

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Primary Oil Price Drivers

Supply side:
- Reserve
- Production capability
- Non-competitive market behavior (gaming)

Demand side:
- Steady demand increase in developed countries
- Increased demand increase in developing countries (China, India)

Others (High volatility and shocks, geopolitical)
Gaming – A General Phenomena

- Gaming is everywhere, from daily life to business, from civil to military
- Interaction between oil supply and demand is also a game
- Oil sand industry has entered in the game, but may not be sufficient to bring down oil price in a certain period of time
- Entry by CTL (coal-to-liquids) may do it
US CTL Option - Important

Not only an economic issue - Energy security, smooth transition to Hydrogen Economy

US Energy Security

EIA forecast of US oil import - if without CTL

![Graph showing US energy consumption and imports over time]

- History:
  - Consumption
  - Domestic Supply

- Projections:
  - Net Imports: 70%
  - Decrease by 54%
No Action -> Danger

Stormy Road Ahead

Energy

Economy
US CTL – We CAN Do It

- The US has the largest coal reserve in the world
  - Nearly 300 billion tons of recoverable reserve

- Coal is one of the largest energy sources in the world
  - China claimed a reserve of over a trillion tons
  - EU, Russia, Australia, India etc. all have considerable reserves
US CTL – We CAN Do It

• The US has the capital
• CTL is mature technology (Sasol has a commercial plant in South Africa since 80s)
• Some US and other international firms demonstrated alternative technologies
• Cost depends on plant size, location etc.
The Gaming Modeling

- To simulate how likely CTL would affect World oil markets?
- Non-cooperative gaming (Cournot-Nash)
- Quantity as the primary control variable (strategy tool)
- Price(s) will be affected by quantities
The Gaming Model

• Linear demand function is used for describing the demand response to price
• Long-run marginal costs (estimates) are used for expansion costs of crude, oil sand and CTL
• Biomass share is deducted from demand
• Uncertainty in demand is quantified as stochastic processes (mean-reversion)
• Risk aversion supply players (utility functions)
The Gaming Model

- PKKT (Pseudo Karush-Kuhn-Tucker) conditions (derivatives)
- MCP (mixed complementarity programming) Solver
- Limited CTL capacity expansion by year
- CTL long-run mean marginal cost is about $38/bbl in 2002 dollars
- Oil sand oil long-run mean marginal cost is about $26/bbl in 2002 dollars
Major Results – Demand Movement
Major Results – Likely Benefits

• CTL can bring down crude oil prices in mid to long-run
• Roughly mean price change caused by CTL:
  By 2017, = - $10/bbl, by 2025, = - $11/bbl
• Energy savings (Assume US import is 12M BPD by 2017):
  By 2017, ~12million bpd x 10 = $120m/day
• Others (Energy security: 2-5million bpd 2017; ...
Incentives for CTL

• CTL could drive down crude oil price down to lower 30s in 2002 dollars, which is less than the likely CTL long-run marginal cost
• Hence, CTL may lose money
• It would be desirable for the US Government to secure price floors for CTL, such as $35/bbl in 2002 dollars, or about $45/bbl in 2007 dollars
• Quantity of US CTL for incentives is around 2 million bpd in 2017 considering that other countries would do similar things (World CTL capacity would be desired to be around 10-20 million bpd 10 years from now)
What We Do at Purdue

• Energy Center, in charge of coordinating energy research at Purdue University
  - Indiana Center for Coal Technology Research (CCTR)
  - State Utility Forecasting Group (SUFG)
  - Coal Transformation Lab
  - Others
Our CTL/Polygen Activities

- Sponsored by CCTR, we (SUFG) have been conducting feasibility studies on potential CTL sites in Indiana, with co-production of power (polygen)
- Physically screened 5 sites
- We have been developing a mathematical model to optimize CTL/polygeneration plants
  - Objective is profit max or cost min
  - Considering various technologies
  - Sites
  - Transportation
  - Coal and material supply chain etc.
Our CTL Activities

• Currently, we are concentrating on the assessment of Crane as a potential CTL site: Transport of large facilities, coal and finished products; water resources; environment issues; utilities and off-sites; other supply chain/logistics etc.

• CCTR – on labor and economic impact

• Indiana Geology Survey IGS – CO2 & Coal availability
Crane
Indiana State Incentives

- State Legislature passed laws on incentives to clean coal projects
- State Government will give $10 million/year tax credits to such projects
- There are also local incentives, depending on the location of each project
- Investment in such projects is welcome by the State
Conclusion

• CTL is a strategic tool for bring down crude oil prices
• Cost of CTL may be a bit high – risk
• Incentives are needed
• Indiana welcomes investment in CTL
• Purdue would like to help facilitate CTL projects
Finally

• Questions?