

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

Invited Presentation to
The Energy & Transportation Panel Meeting
April 25-26, 2007, Detroit, MI

Zuwei Yu, Akiner Tuzuner, Paul Preckel

Energy Center at Discovery Park
Purdue University

zyu@purdue.edu

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)

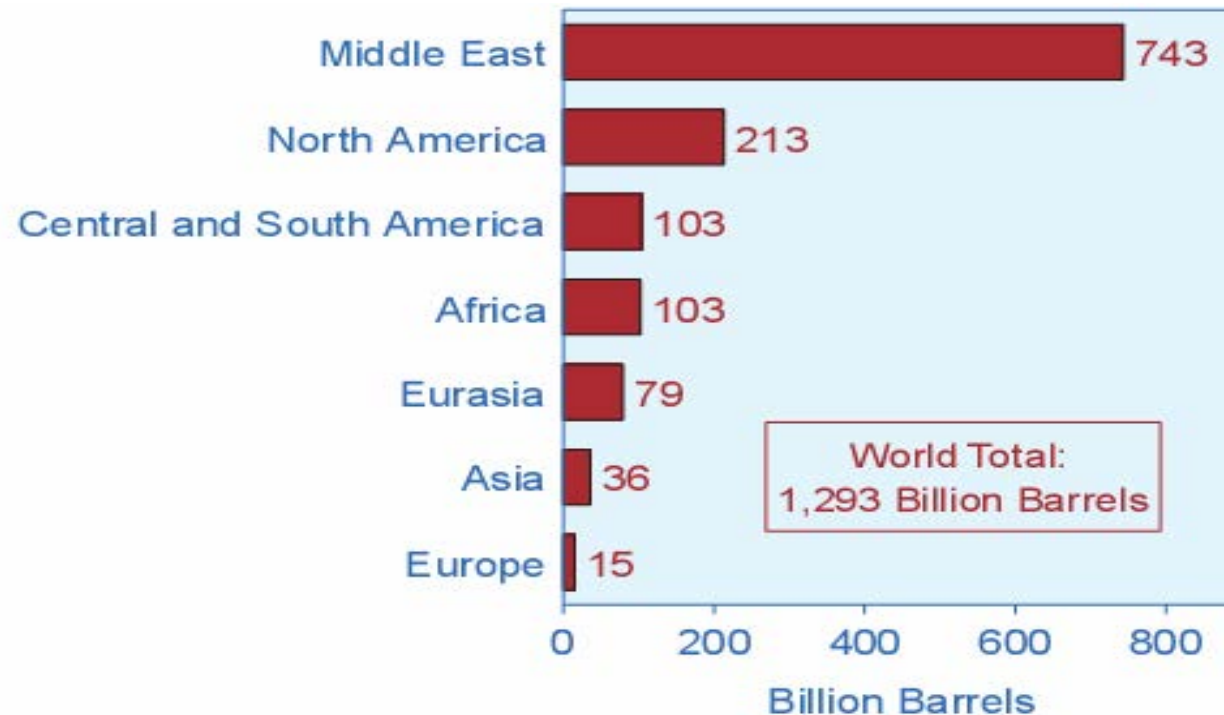
Others (High volatility and shocks, geopolitical)

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

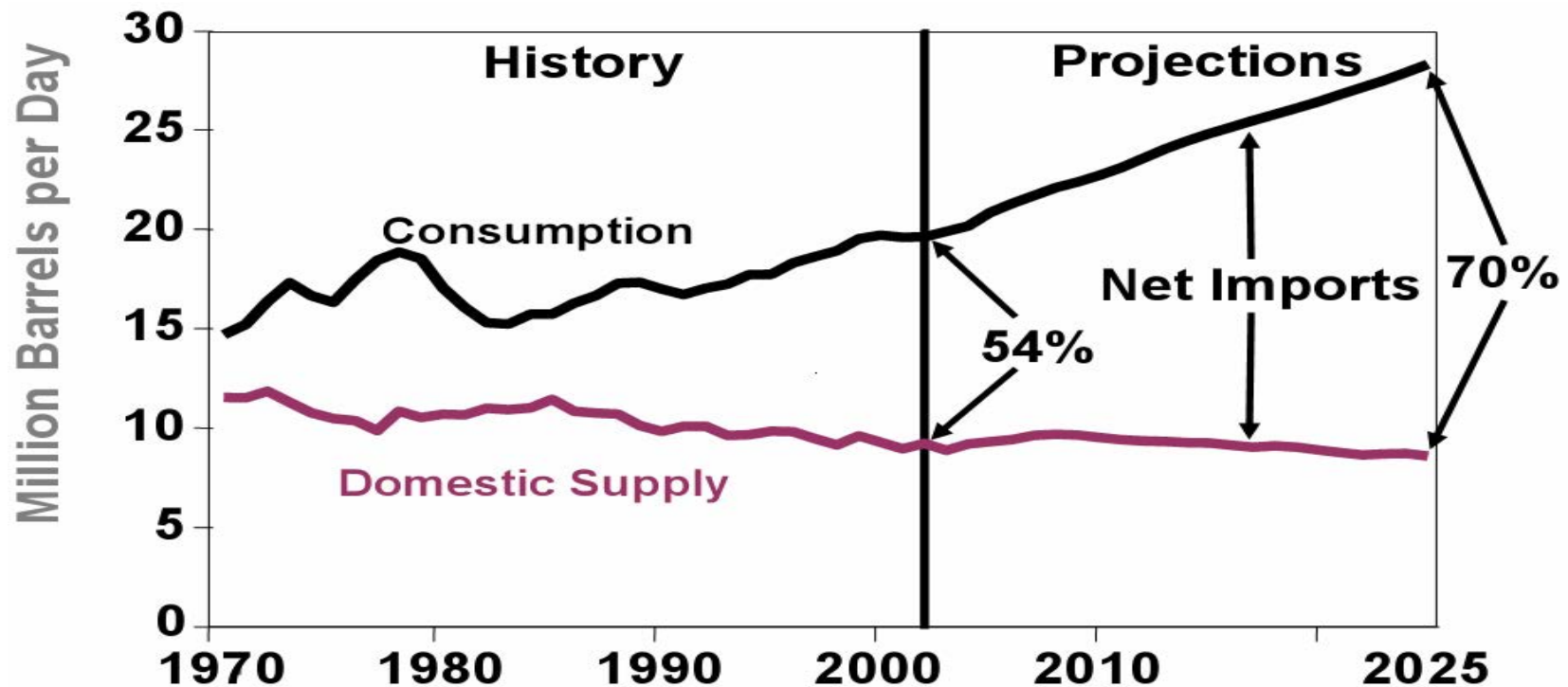
Not only an economic issue - Energy security,
smooth transition to Hydrogen Economy



Source: "Worldwide Look at Reserves and Production," *Oil & Gas Journal*, Vol. 103, No. 47 (December 19, 2005), pp. 24-25.

US Energy Security

EIA forecast of US oil import - if without CTL



No Action -> Danger

Stormy Road Ahead



US CTL – We CAN Do It

- The US has the largest coal reserve in 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

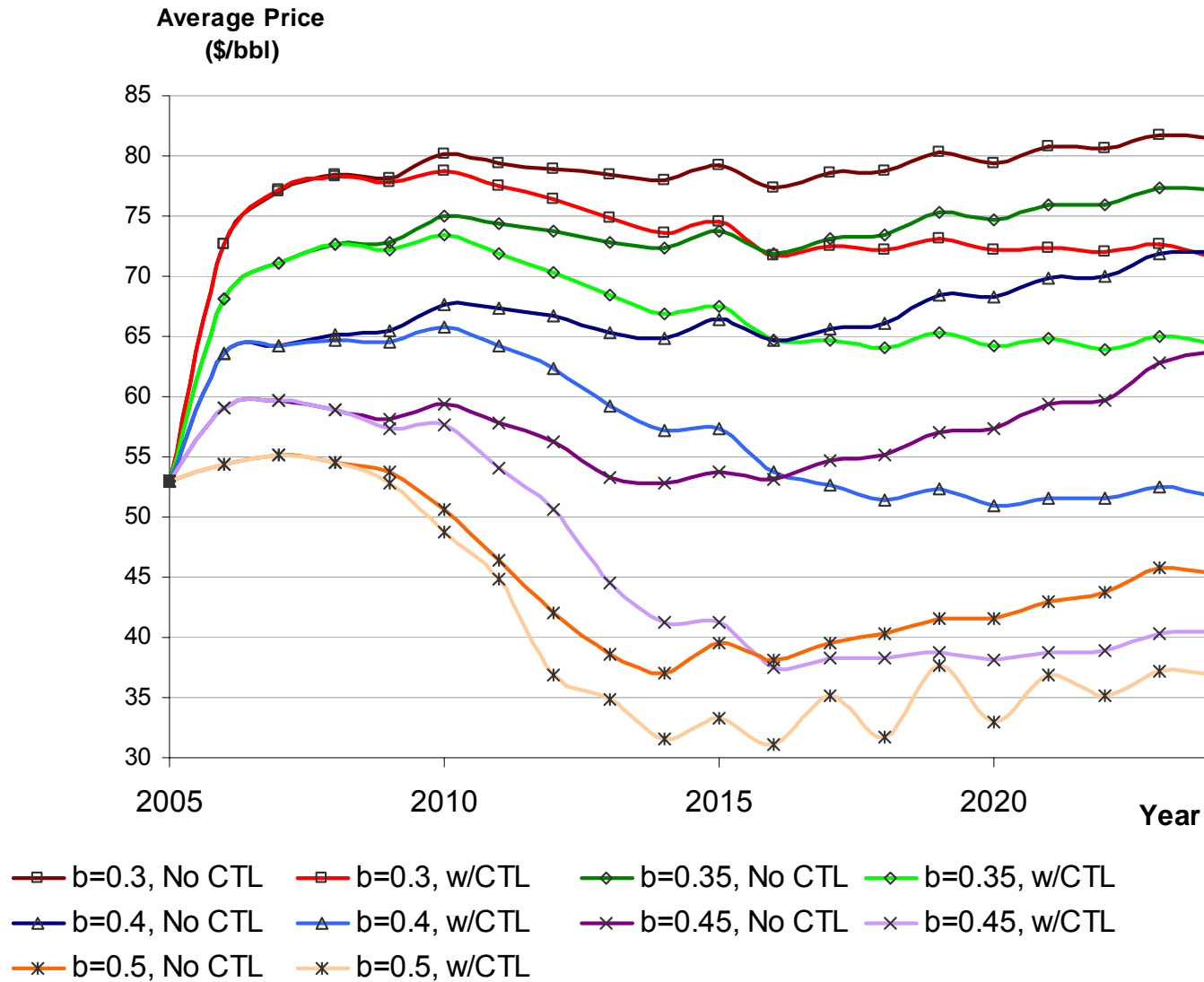
The Gaming Model

- 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)

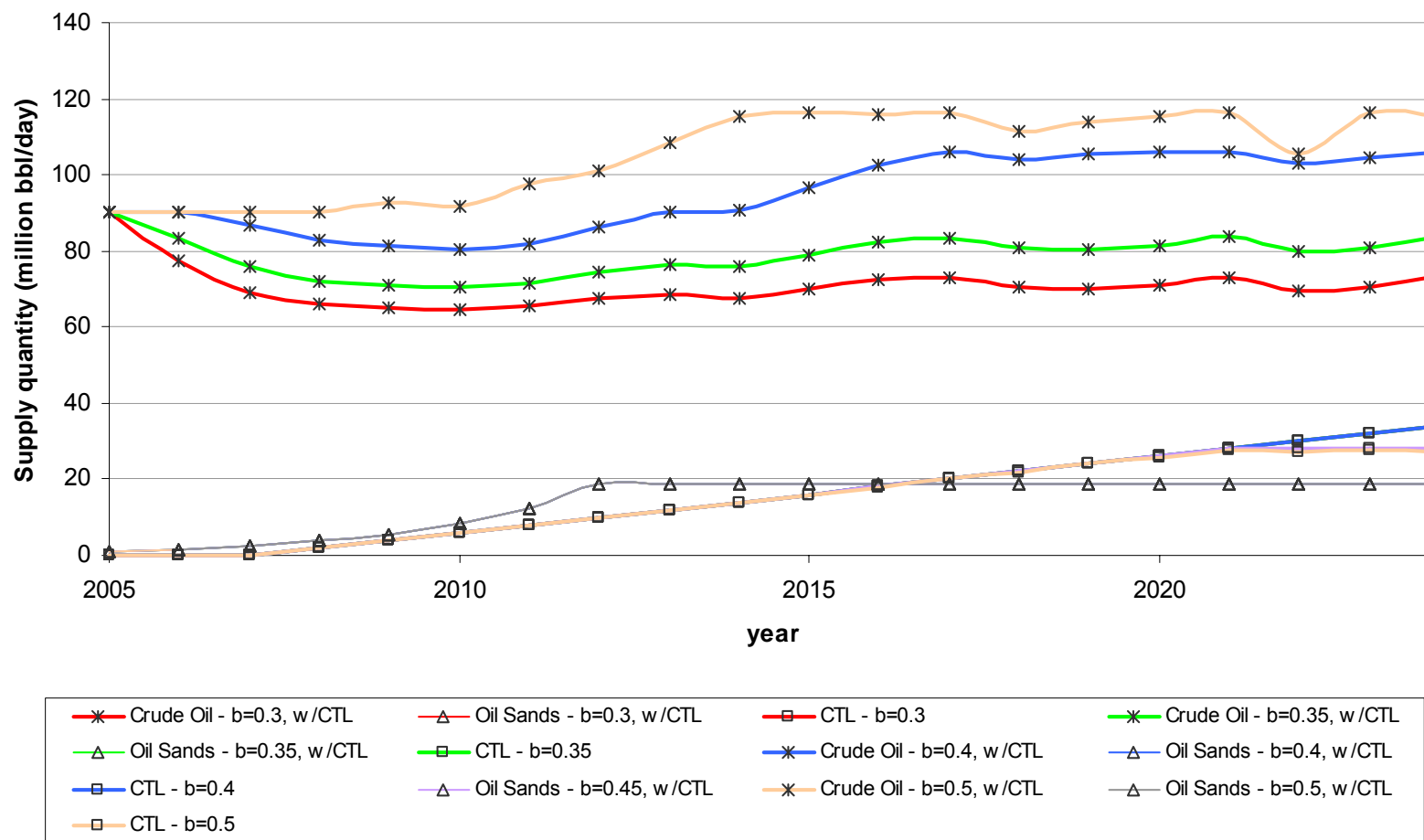
The Gaming Model

- 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 – Price Movement



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, $\sim 12 \text{ million bpd} \times 10 = \120 m/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 loose 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

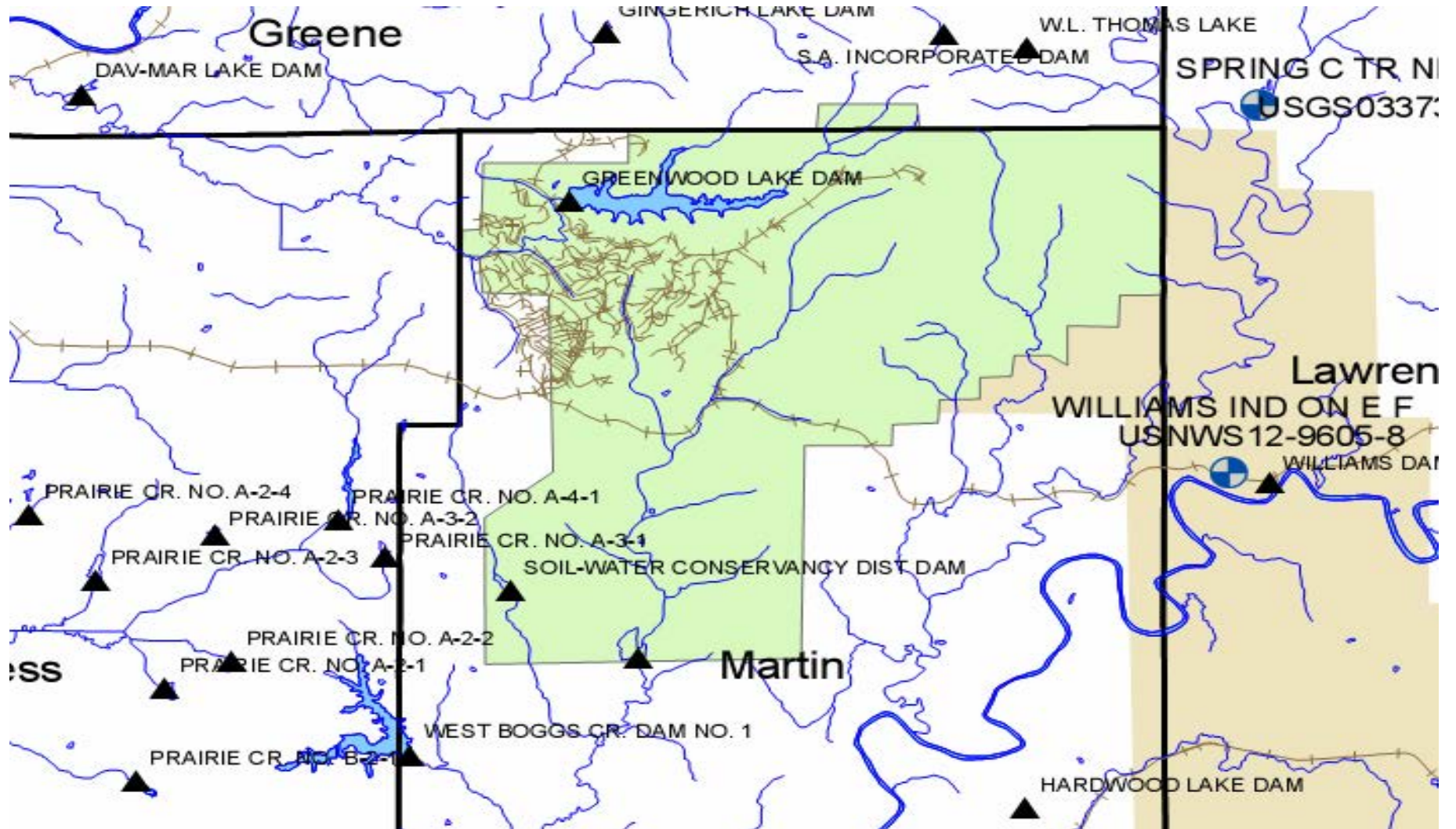
Our CTL/Polygen Activities

- 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?