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)

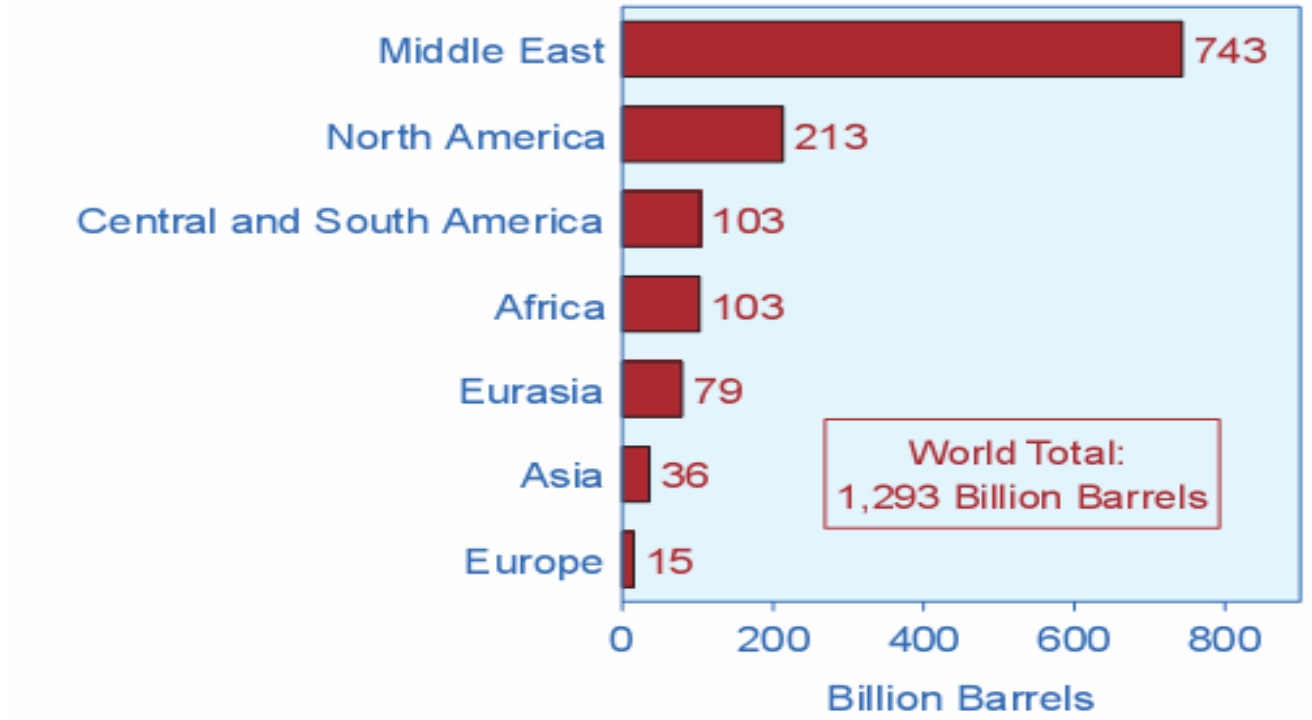
Others (High volatility and shocks, geopolitical)

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

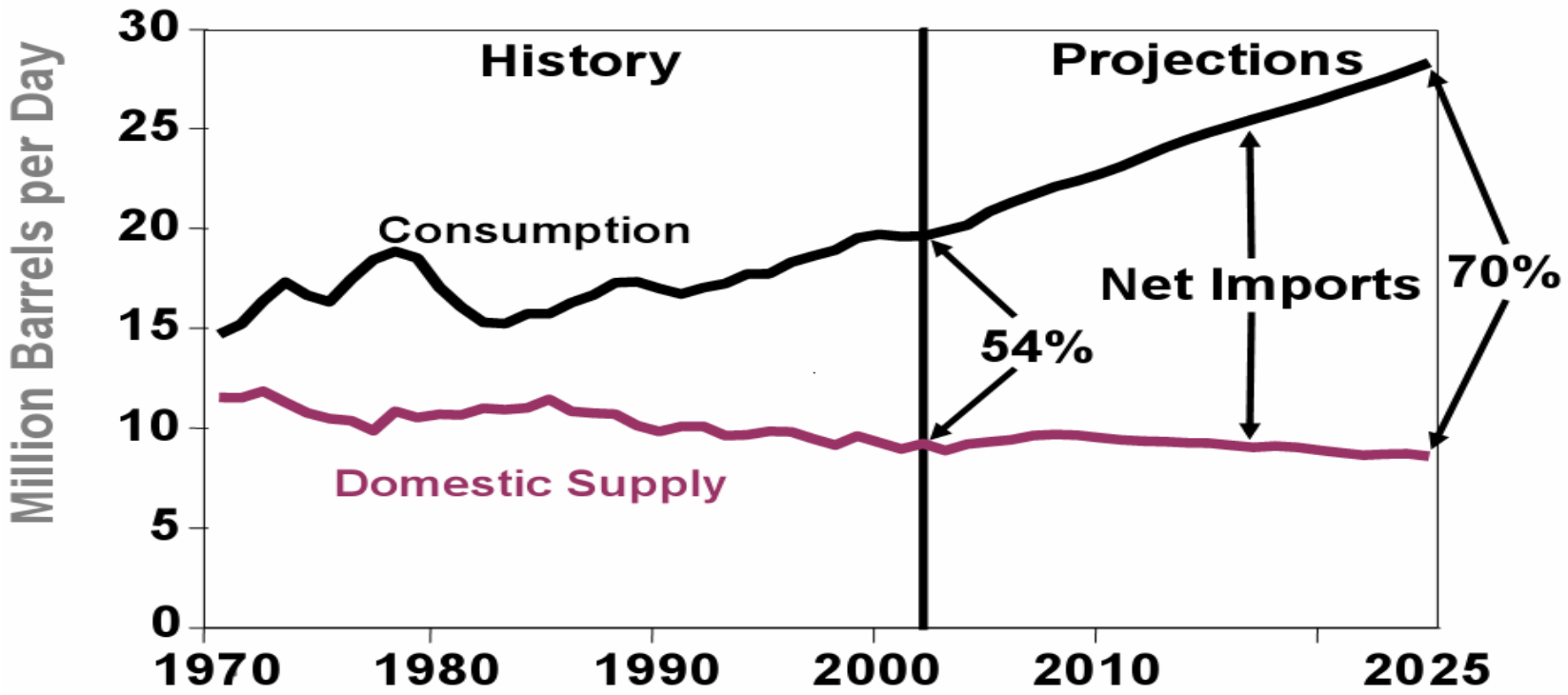
Not only an economic issue - Energy security, smooth transition to Hydrogen Economy



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

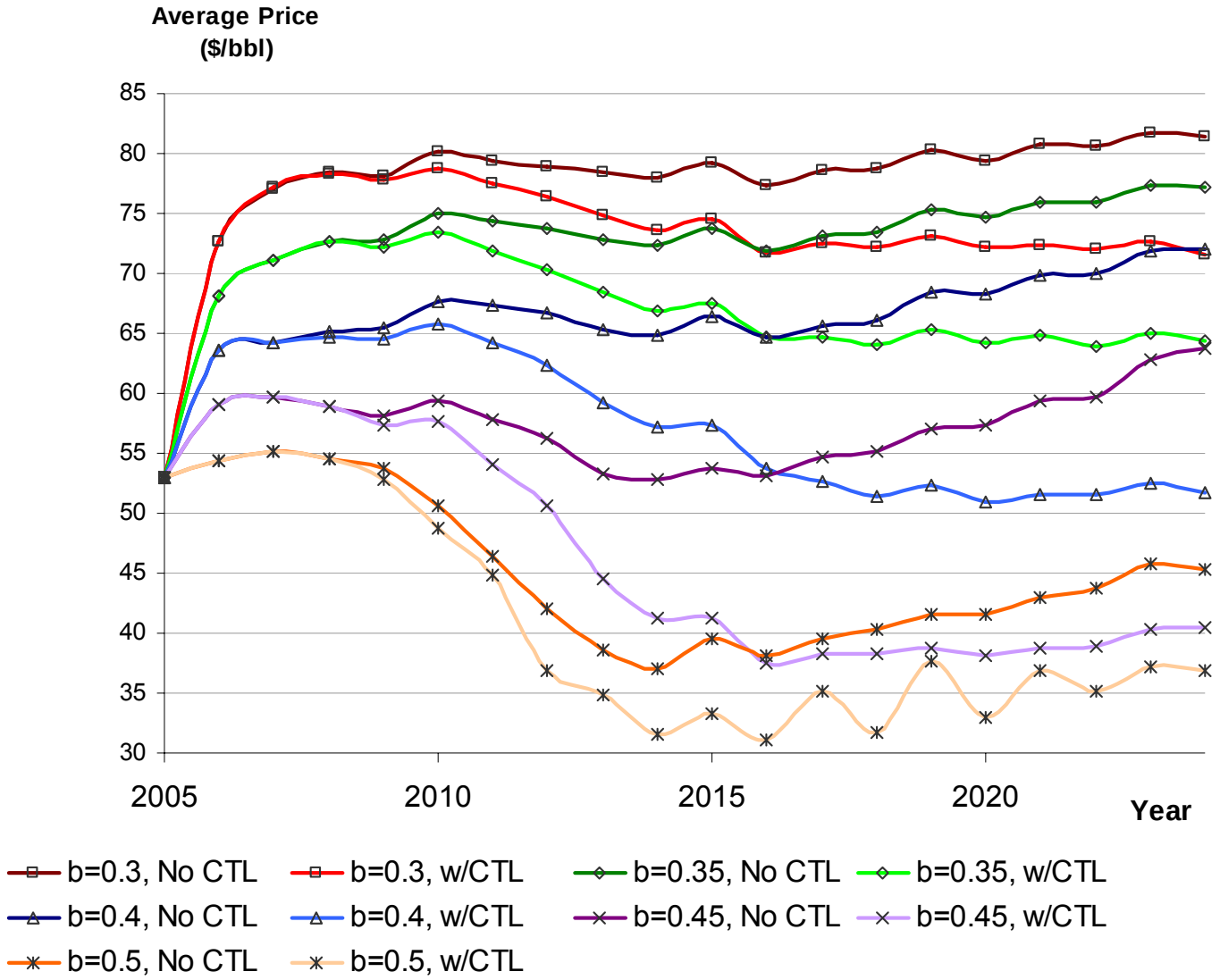
The Gaming Model

- 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)

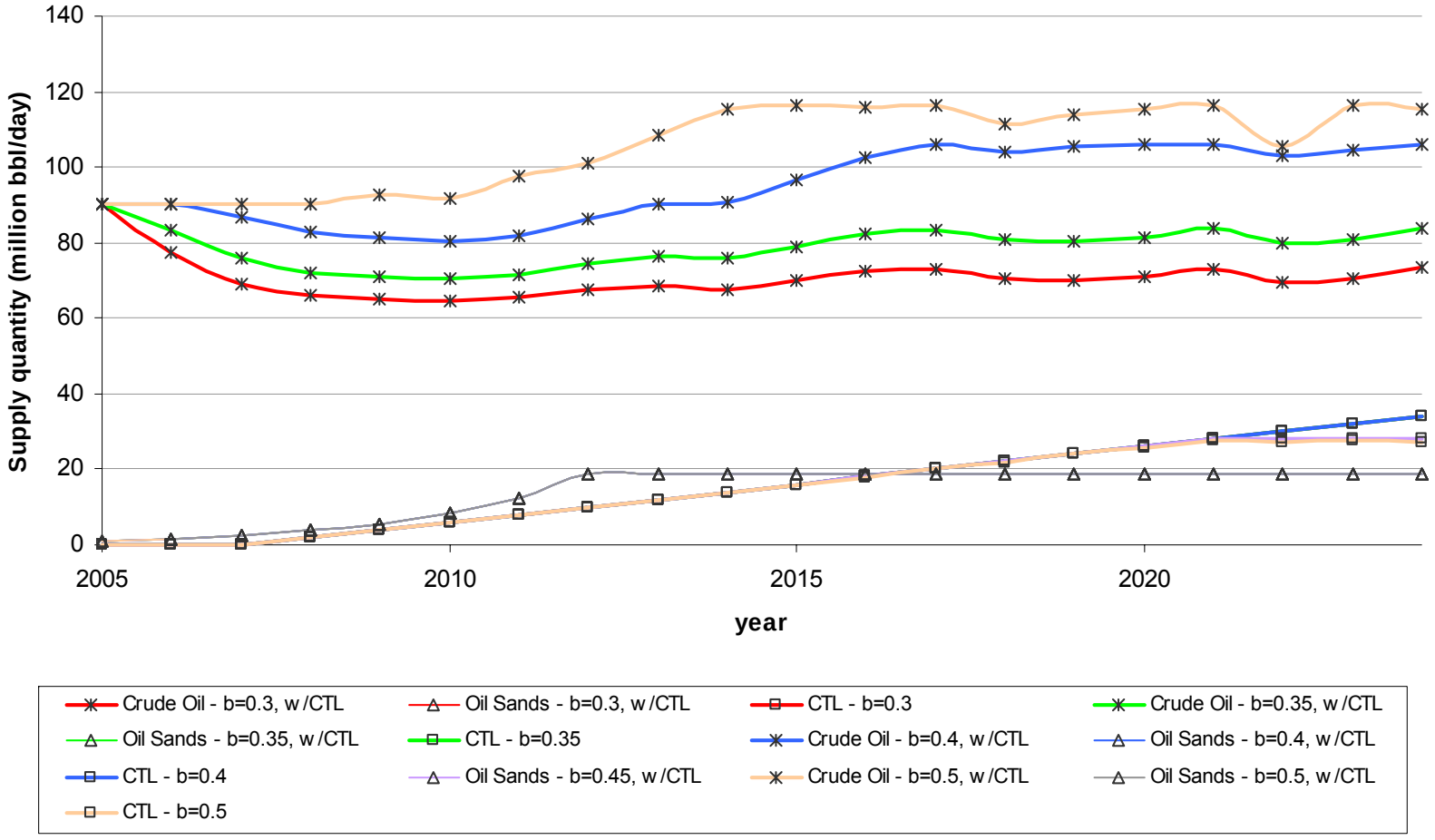
The Gaming Model

- 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, ~12million bpdx10=$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 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

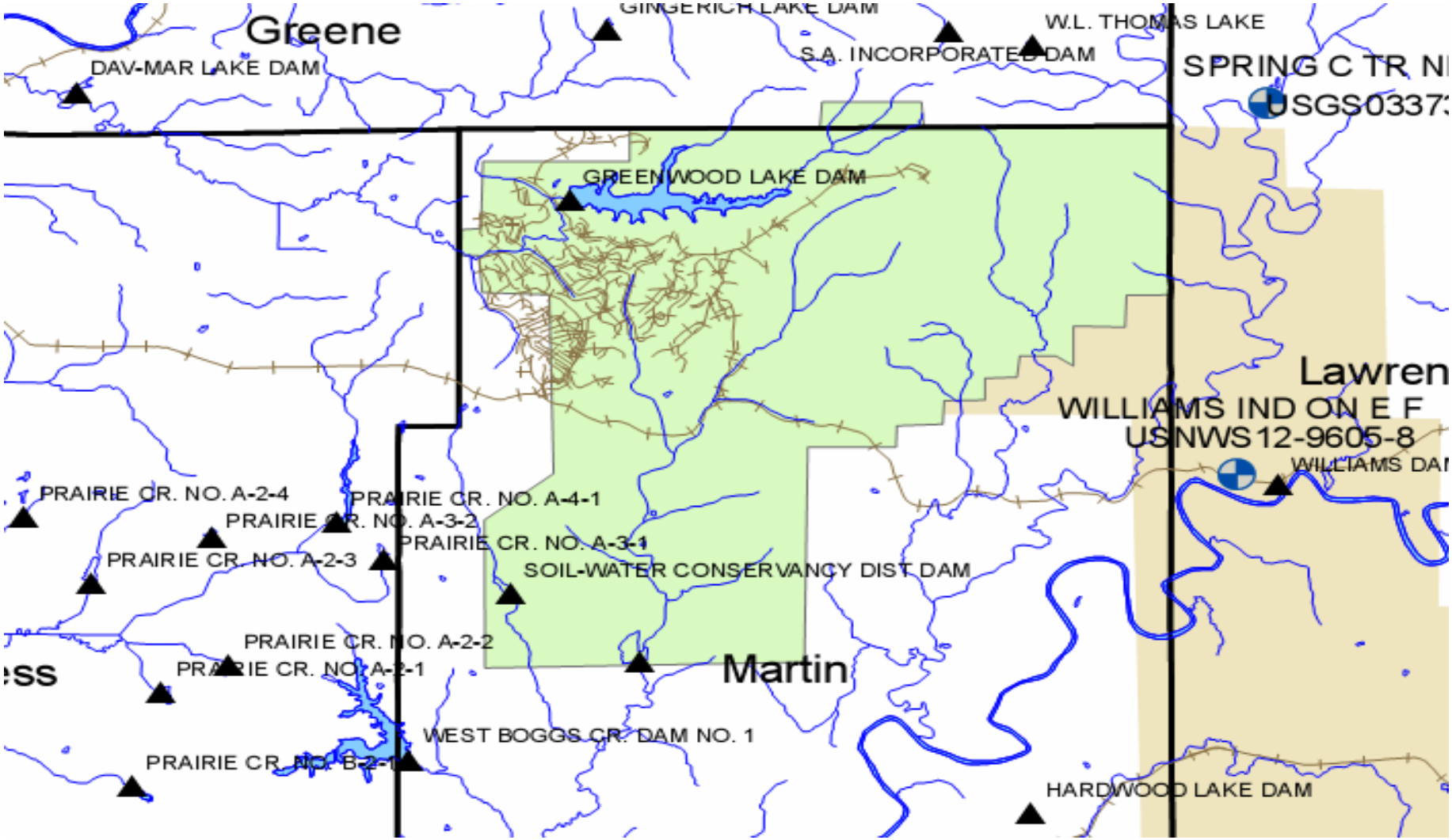
  Objective is profit max or cost min

- 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


Greene
DAV-MAR LAKE DAM
GINGERICH LAKE DAM
W.L. THOMAS LAKE
S.A. INCORPORATED DAM
SPRING C TR NI
USGS0337
GREENWOOD LAKE DAM
Lawren
WILLIAMS IND ON E F
USNWS12-9605-8
WILLIAMS DAM
PRAIRIE CR. NO. A-2-4
PRAIRIE CR. NO. A-4-1
PRAIRIE CR. NO. A-3-2
PRAIRIE CR. NO. A-3-1
PRAIRIE CR. NO. A-2-3
SOIL-WATER CONSERVANCY DIST DAM
PRAIRIE CR. NO. A-2-2
PRAIRIE CR. NO. A-2-1
Martin
WEST BOGGS CR. DAM NO. 1
PRAIRIE CR. NO. B-2-1
HARDWOOD LAKE DAM

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?