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World Gas Trade Model

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What does the model capture?

- World gas supply potential is large
  - But it is concentrated in areas remote from markets
  - Also, some of these areas have limited production and transport infrastructure in place
  - Some large resources are located in countries that may be politically and/or economically unstable

- Potential for demand growth is large
  - China, India, and other less developed countries
  - Environmental pressure for cleaner fuels

- Model gives a microeconomic framework to examine alternative political and economic phenomena that could affect the market
Basic model structure

- Model based on *Market Builder* from *Altos Partners*
  - Access to the model requires a license from *Altos*
- Dynamic spatial equilibrium linked through time by optimal scheduling of resource extraction
  - Eliminate opportunity for *either* spatial or temporal arbitrage
    - Producers consider all *current and future* prices when determining the profitability of developing a unit of reserves
    - Producers, therefore, maximize the *net present value* of resource extraction for the life of the investment
  - If producers *anticipate* prices in period $t$ will be high, they
    - Accelerate investment to take advantage of those prices
    - Delay some supply from periods before $t$
    - Actual prices at $t$ thus do not rise as much
- Transport links transmit prices as well as gas
  - A link to a market with high prices will raise prices at the origin supply node
- Non-stochastic framework that predicts prices, flows
Demand for Natural Gas

- Demand has been stimulated by
  - Actual and proposed environmental regulations
  - Pro-competitive deregulation of wholesale electricity markets
  - Development of CCGT
  - Economic and population growth which increase the demand for energy

- Possible future developments?
  - Gas may become a transport fuel via a number of alternative routes
  - Alternatives (solar, nuclear, coal gasification) may displace gas in electricity production
  - HVDC may displace gas transportation
Market structure

- Expanding depth and geographical extent of the gas market
  - Reduces the risk associated with investing in infrastructure
  - Decrease in average distances between suppliers and/or customers increases arbitrage opportunities

- *Expectation* of new market dynamics encourages the transition
  - Change in market structure can happen quickly

- Swaps can eliminate high cost contracted trades if better alternatives are available
Estimating energy demand

- Used 23 years of IEA data from 29 OECD economies to relate energy demand to:
  - Overall level of economic activity (GDP)
  - Population, and
  - Economic development (GDP/capita)

- Following Medlock and Soligo (2001), we allow energy demand to increase less with GDP growth as an economy develops:
  - Coefficient on GDP goes to zero as per capita GDP approaches 12 times US level (85 years @ 3% pa)
  - Increased population without a change in GDP decreases energy use
  - Effects accumulate over time
Estimated gas share

- Depends negatively on own price, positively on prices of competing fuels

- Level of development as measured by GDP per capita alters effect of the “scale variable” GDP on the gas demand share
  - At lower levels of development, increased GDP does more to increase the demand share of gas
  - Per capita GDP where gas share stops increasing is close to value where energy demand stops growing

- Again adjustments occur gradually in response to changes
Forecasting demand

- World Bank *Economic Indicators* forecasts of:
  - GDP growth
  - Population growth

- EIA base case oil price forecasts and historical coal/oil price ratio used to forecast alternative fuel prices

- For output discussed below, we used EIA base case demand forecasts with estimated own-price elasticity

- Forecasts using above demand methodology available on Baker web site after conference
Sources of Natural Gas supply

- We use the resource estimates of the USGS:
Proved Natural Gas Reserves by Region, 2003

World Total: 5501.424 TCF
North America: 4.587%
Eastern Europe/FSU: 35.7%
Western Europe: 3.48%
Middle East: 35.98%
Asia & Oceania: 8.01%
Africa: 7.6%
Central/South America: 4.55%

Units: Trillion Cubic Feet
Source: USGS
Undiscovered Natural Gas by Region, 2001 estimates

Units: Trillion Cubic Feet
Source: USGS
More detail on supply

- Regional resource potential as in the P-50 resource estimates from the *World Resource Assessment* of the USGS including
  - associated and unassociated natural gas resources
  - both conventional and unconventional gas deposits in North America, and
  - conventional gas deposits in the rest of the world

- Resources are divided into three categories:
  - proved reserves,
  - growth in known reserves, and
  - undiscovered resource

- Resource cost estimates developed as part of the Altos-USGS CRADA.
**Scheduling supplies**

- Optimal extraction rate for a particular deposit depends on:
  - current and expected future prices net of transport costs,
  - total available resources,
  - capital cost of development,
  - operating and maintenance costs, and
  - production decline profiles by region and type of deposit

- Model also determines new transportation capacity expansion from supply sources to demand sinks based on:
  - capital costs of expansion, and
  - operating and maintenance costs of utilizing new and existing capacity

- Supplies earning greatest rents are extracted first

- Disadvantages supplies isolated from end-use markets or in locations that lack prior infrastructure development.
Example cost of supply curves

Comparative Cost of Supply Curves for Select Regions

$/Mcf

Cumulative Reserve Additions (Tcf)

- West Siberia
- Qatar
- Saudi Arabia
- North Alaska
Pipeline link example
Representing transport networks

- Pipeline networks in North America and Europe are main transportation system
  - LNG about 5% of world demand, but important in Japan, Korea, becoming important in US
- Aggregate supply and demand into discrete “nodes”
- Aggregate parallel pipes into a single link
  - Ignore minor distribution and gathering pipes
- Transport links are inherently discrete
  - Allow many potential links
  - Use a hub and spoke representation for LNG
LNG transportation network
Pipeline costs

- EIA has published project specific data for 52 pipeline projects
- Relate specific capital cost (annual cost per unit of capacity) to project characteristics
  - Project cost is raised by:
    - Length
    - Crossing mountains
    - Moving offshore or crossing a lake or sea
    - Developing in more populous areas
  - Higher capacity reduces per unit costs as a result of scale economies
**LNG costs**

- Consulted a variety of sources and industry contacts

- Shipping costs split into a fixed capital cost for ship development plus operating costs of:
  - 2.25% of fixed cost of development
  - fuel use during transit (0.15% per day)

- Liquefaction costs are a fixed cost ($4.11/mcf/yr) plus a variable feed gas cost

- Regasification costs vary by location (land costs)
# Indicative LNG costs

Price required for expansion, including capital costs

<table>
<thead>
<tr>
<th>Route</th>
<th>Feed gas</th>
<th>Liquefaction</th>
<th>Shipping</th>
<th>Regasification</th>
<th>Total cost</th>
<th>Model outcome</th>
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</thead>
<tbody>
<tr>
<td>Trinidad to Boston</td>
<td>$0.63</td>
<td>$1.02</td>
<td>$0.83</td>
<td>$0.69</td>
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<td>Algeria to Gulf of Mexico</td>
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<td>$1.00</td>
<td>$1.82</td>
<td>$0.39</td>
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<td>NW Shelf to Baja</td>
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<td>Norway to Cove Point</td>
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<td>$1.14</td>
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</table>
Selected price projections
LNG share of world supply by source

- Atlantic Basin
- Middle East
- Pacific Basin
Major exporter projections

Share in rest of world demand

- Malaysia
- Indonesia
- Australia
- North Africa
- South America
- Iran
- Qatar
- Saudi Arabia
- Russia
Major importer projections

Net import share in own demand