IGCC
(Integrated Gasification Combined Cycle)
Technology Overview

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Presentation Outline

- Brief Introduction of Nexant
- IGCC Technology Background
- Comparison of Performance, Cost, and Emission with Other Generation Technologies
- Potential Technical Advancements for IGCC Plants
- Expansion of IGCC for Poly-Generation
- Barriers of Using IGCC in India and China
- Conclusions
Brief Introduction of Nexant

Dr. Tan-Ping Chen
Nexant, Inc.
What is Nexant?

- Used to be Bechtel Technology & Consulting, spun off in Jan. 2000; Bechtel has US$17 billion annual sale

- Bechtel is the majority owner; other investors include Morgan Stanley, Mitsubishi Capital, IBM, First Technology

- Headquarter in San Francisco with offices in London, DC, and White Plains (NY), Mesa (AZ), Denver, Houston, LA

- Started with 150 people, grew to 250 by acquisition

- Main business: consulting & technology development services in energy area

# Energy Technology Business Line

<table>
<thead>
<tr>
<th>Type of Work</th>
<th>Technologies</th>
<th>Clients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project feasibility/planning studies</td>
<td>Gasification to make power, SNG, hydrogen, methanol, ethanol, DME, MTO, ammonia, and other chemicals</td>
<td>UNDP, UNIDO, GEF</td>
</tr>
<tr>
<td>Engineering &amp; construction of pilot units and demonstration plants</td>
<td>Direct and indirect coal liquefaction</td>
<td>ADB</td>
</tr>
<tr>
<td>Owner's engineer for commercial plants</td>
<td>Biomass and garbage conversion</td>
<td>USAID</td>
</tr>
<tr>
<td>Technology survey</td>
<td>Gas turbine, combined cycle, reciprocating engines</td>
<td>USTDA</td>
</tr>
<tr>
<td>Technology investment due diligence</td>
<td>PC, FBC, cogeneration</td>
<td>USDOE</td>
</tr>
<tr>
<td>Market study</td>
<td>Emission controls</td>
<td>NEDO</td>
</tr>
<tr>
<td>Lender's engineer</td>
<td>CO2 capture from syngas and flue gas</td>
<td>EPRI</td>
</tr>
<tr>
<td>Arbitration</td>
<td>Hydrogen, fuel cells, distributed power generation</td>
<td>Private electric/gas utilities (Virginia Power, Baltimore G&amp;E, Tokyo Electric, SCE, etc)</td>
</tr>
<tr>
<td>Technology Development</td>
<td>Solar power</td>
<td>Private oil/gas/chemical companies (Shell, Chevron, BP, DuPont, etc)</td>
</tr>
<tr>
<td></td>
<td>Oil shale, tar sands</td>
<td>Technology developers (Alstom, GE, RTI, etc)</td>
</tr>
<tr>
<td></td>
<td>Waste coal utilization</td>
<td>Investors, IPP</td>
</tr>
</tbody>
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![Nexant Logo](logo.png)
Gasification Experience

- Built 100 MW Cool Water IGCC demonstration plant
- Built 1300 tpd coal to chemicals (methanol, acetic acid, and acid anhydride) plant for Eastman
- Built 250 MW IGCC plant at Tampa Electric in Florida
- Built LuNan 500 tpd coal to ammonia plant
- Conducted Shanghai Wujing tri-generation feasibility study under USTDA funding
- Owner’s engineer for US$650 million clean coal project for USDOE and WMPI to co-produce FT liquid and electricity
- Owner’s engineer to Reliance for a $2 billion coke gasification plant in India
- Conducting $2 million India IGCC study for NTPC under USAID funding
- Conducting $0.55 million polygeneration feasibility study for HITS in Shenyang under USTDA funding
- Conducting a coal-to-liquid study in Mongolia for QGX
- Conducted more than 130 other gasification feasibility studies
IGCC Technology Background
Why IGCC?

- High efficiency: due to CC; GT steadily increases efficiency
- Young Technology: amply room for advancements & improvements
- GHG reduction:
  - by high efficiency
  - Low syngas volume (15-20% of PC flue gas) to facilitate CO₂ capture
- Low SOx and NOx:
  - H₂S is much easier to remove than SO₂
  - Pollution control is easier for gas firing: lean burner, steam injection, SCR
- Low water consumption: 2/3 power from GT
Major Types of Coal Gasifiers

Moving Bed (1st Generation)

Entrained Bed (3rd Generation)

Fluidized Bed (2nd Generation)

Transport (variation of fluid bed)
Entrained Bed Gasifier

- Most commercial gasifiers are this type
- Very high temperature to provide good carbon conversion for any grade of coal
- Heavy metals in ash can be encapsulated in glass-like slag
- Slurry feed type (GE, E-Gas) and dry feed type (Shell, Prenflow, Noell)
- Hot syngas from GE gasifier can be cooled not only by WHB but also water quench
Other Types of Gasifiers

**Fluidized Bed**
- U-Gas gasifier (developing)
- HT Winkler gasifier (commercial, RWE idle)
- No slagging
- Medium oxidant use
- Medium cold gas efficiency
- Good for high ash, high reactivity coals

**Transport**
- KBR gasifier (developing)
- No slagging
- Medium oxidant use
- Medium cold gas efficiency
- High throughput
- Good for high ash, high reactivity coal

**Moving Bed**
- Lurgi gasifier (commercial)
- No slagging
- Low oxidant use
- High cold gas efficiency
- Require lump coal
- Require non-caking coal, high steam use
- Liquid products Issues
Gasification Capacity by Applications

MW \text{th}

\begin{tabular}{|l|c|c|}
\hline
& syngas & \\
\hline
Power & \includegraphics[width=0.5\textwidth]{power.png} & \\
Chemicals & \includegraphics[width=0.5\textwidth]{chemicals.png} & \\
F-T Liquids & \includegraphics[width=0.5\textwidth]{ftliquids.png} & \\
Gaseous Fuels & \includegraphics[width=0.5\textwidth]{gaseousfuels.png} & \\
\hline
\end{tabular}

- Planned
- Real
Eastman Coal to Chemicals Plant
Wabash 250 MW IGCC Plant
Puertollano 310 MW IGCC Plant
# Coal Based IGCC Plants

<table>
<thead>
<tr>
<th>Project/Location</th>
<th>Combustion Turbine</th>
<th>Gasification Technology</th>
<th>Net Output MW</th>
<th>Start-Up Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wabash River, IN</td>
<td>GE 7 FA</td>
<td>Global Egas (formerly Destec)</td>
<td>262</td>
<td>Oct 1995</td>
</tr>
<tr>
<td>Tampa Electric, FL</td>
<td>GE 7 F</td>
<td>GE (formerly Texaco)</td>
<td>250</td>
<td>Sept 1996</td>
</tr>
<tr>
<td>Demkolec (now Nuon), Buggenum, NL</td>
<td>Siemens V 94.2</td>
<td>Shell</td>
<td>253</td>
<td>Jan 1994</td>
</tr>
<tr>
<td>ELCOGAS Puertollano, Spain</td>
<td>Siemens V 94.3</td>
<td>Krupp-Uhde Prenflo</td>
<td>310</td>
<td>Dec 1997</td>
</tr>
</tbody>
</table>
Many Gasification Projects in Planning in North America

- American Electric Power
- Agrium/Blue Sky AK
- Baard Generation OH
- BP/Edison Mission CA
- Cash Creek Generation KY
- Clean Coal Power IL
- DKRW WY
- Duke/Cinergy IN
- Energy Northwest WA
- Erora Group IL
- Excelsior Energy MN
- First Energy/Consol OH
- Leucadia National LA
- Madison Power IL
- Mountain Energy ID
- NRG Energy DL
- Orlando Util/Southern FL
- Otter Creek MT
- Power Holdings IL
- Rentech MS
- Royster Clark/Rentech IL
- Southeast Idaho ID
- Steelhead Energy IL
- Synfuel OK
- Tampa Electric
- WMPI PA
- Xcel Energy CO

Most projects are for power, but also SNG and liquid fuels; Many also use petcoke; Many projects also in other countries
Comparison of Performance, Cost, and Emissions with Other Generation Technologies

Dr. Tan-Ping Chen
Nexant, Inc.
IGCC Plant Energy Flow & Efficiency

100MW

12MW

18MW

15MW

80MW

30MW

Net Coal to Power: $30 + 10 = 40\%$
COMPARISON OF EFFICIENCY

HHV Efficiency (%)

<table>
<thead>
<tr>
<th></th>
<th>IGCC with CO2 capture</th>
<th>Avg IGCC with CO2 capture</th>
<th>PC Sub with CO2 capture</th>
<th>PC Sub with CO2 capture</th>
<th>PC Super with CO2 capture</th>
<th>PC Super with CO2 capture</th>
<th>NGCC with CO2 capture</th>
<th>NGCC with CO2 capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>39.0</td>
<td>31.5</td>
<td>36.3</td>
<td>23.9</td>
<td>26.9</td>
<td>50.6</td>
<td>43.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Impacts of CO2 Capture:
- 20% hit on IGCC
- 30% hit on PC
COMPARISON OF CAPITAL COST

Impacts of CO2 Capture:
- 33% hit on IGCC
- 75% hit on PC
COMPARISON OF GENERATION COST

Coal cost $1.34/10^6Btu
Gas cost $7.46/10^6Btu

Impacts of CO2 Capture:
- 30% hit on IGCC
- 70% hit on PC
The Wabash River Plant in Terre Haute, Indiana, was repowered with gasification technology.
Tampa Electric (TECO) Clean Coal Project
A Case Study for Cleaner Air

Older Coal Plant: 2.07 lb/Million Btus
Fleet Avg.: 1.2 lb/Million Btus
TECO CCT Plant: 0.1 lb/Million Btus
Older Coal Plant: 0.47 lb/Million Btus
Fleet Avg.: 0.07 lb/Million Btus
TECO CCT Plant: 0.07 lb/Million Btus

SO₂:
- Older Coal Plant: 2.07 lb/Million Btus
- Fleet Avg.: 1.2 lb/Million Btus
- TECO CCT Plant: 0.1 lb/Million Btus

NOₓ:
- Older Coal Plant: 0.47 lb/Million Btus
- Fleet Avg.: 0.07 lb/Million Btus
- TECO CCT Plant: 0.07 lb/Million Btus

TECO's coal-to-gas plant in Polk County, FL, is the pioneer of a new type of clean coal plant.
Plant Availability

- PC (commercial record):
  - 90-95%

- IGCC (maximum achieved):
  - Tampa Electric: 81%
  - Wabash: 85%
  - Puertollano: 75%
  - Buggenum: 86%
Potential Technical Advancements for IGCC Plants

Dr. Tan-Ping Chen
Nexant, Inc.
Dry Solids Pump for High Pressure Coal Feed to Gasifier

- **Principle:**
  - Uses pulverized coal under mechanical pressure to maintain high pressure seal to gasifier

- **Benefit:**
  - Reduce heat penalties with slurry feed and high-moisture (western) low-rank coals
  - 0.2-1% plant efficiency increase
  - $20-100/kW capital cost reduction

Stamet Posimetric® Feeder System

Nexum
RTI Warm Gas Cleanup

- Sulfur removal @ 800-900 °F by attrition-free solid sorbent
- PDU tests at Eastman confirmed sulfur removal down to 5 ppmv
- Comparison with cold gas cleanup:

<table>
<thead>
<tr>
<th></th>
<th>MDEA</th>
<th>Rectisol</th>
<th>WGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasification</td>
<td>67.6</td>
<td>67.6</td>
<td>67.6</td>
</tr>
<tr>
<td>Low Temp Gas Cooling</td>
<td>12.3</td>
<td>12.3</td>
<td>0</td>
</tr>
<tr>
<td>Sulfur Removal and</td>
<td>48.2</td>
<td>77.3</td>
<td>43.1</td>
</tr>
<tr>
<td>Recovery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance of Plant</td>
<td>246.1</td>
<td>260.6</td>
<td>234.5</td>
</tr>
<tr>
<td>Total Cost ($ MM)</td>
<td>374.2</td>
<td>417.8</td>
<td>345.2</td>
</tr>
<tr>
<td>Savings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$/kW</td>
<td>$114</td>
<td>$279</td>
<td></td>
</tr>
<tr>
<td>COS Hydrolysis Needed</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Residual Sulfur, ppmv</td>
<td>50-100</td>
<td>&lt;1</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>
ITM (Ionic Transport Membrane)  
Air Separation

- Oxygen ionized to transport through ceramic membrane at 1800 °F for separation from air stream
- Tested at Sparrows Point in January 2006 produced >95% purity oxygen
- Oxygen plant cost and power consumption are reduced more than 35%
- IGCC plant efficiency is reduced by 2% and cost reduced by 7%

Subscale engineering prototype ITM test unit at APCI's Sparrows Point gas plant

FY06 – 5 TPD test module
FY08 – 150 TPD test module
FY09 - Offer commercial modules
Capital Cost Timeline

- Baseline
- Dry Feed
- Refractories
- Warm Gas
- Cleaning; 85% Capacity Factor
- ITM
- Advanced Syngas Turbine; 90% Capacity Factor
- 7FB with SCR
- CO₂ Capture

Year of Pre-Commercial Demonstration

Capital Cost ($/kW)
Expansion of IGCC to Polygeneration
Poly-Generation

Coal → Gasifier → Raw Gas → Shift, Cleanup, CO₂ Removal → Tailored Gas → Chemical Synthesis → Methanol

Combined Cycle

Power, Steam, Hot Water

Suppl Fuel Gas → CO₂ → Purge Gas

F-T Liquids, Ethanol, H₂, NH₃, SNG

Olefins (feeds to make petrochemicals) → MTO or MTP → DME (replace LPG) → Dehydration

Nexant
Reasons for Poly-Generation

- Too many ways to produce power from coal & other energy sources (PC, CFBC, nuclear, hydro, wind, etc.)
- IGCC is too expensive now to compete for power generation; needs environmental benefits as the driver
- Power produced as byproduct; cheaper and very clean
- Coal is hydrocarbon sources; liquid fuels for transportation & petrochemicals are deal as replacement for the every more expensive petroleum
- Liquid fuels & chemicals are much higher value products than coal; solve shipping cost issue of coals in remote areas
- Has partial benefit of GHG reduction
## Comparison of Methanol with Gasoline for Transportation

<table>
<thead>
<tr>
<th></th>
<th>Gasoline</th>
<th>Methanol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Molecular Formula</strong></td>
<td>$\text{C}<em>7\text{H}</em>{15}$</td>
<td>$\text{CH}_3\text{OH}$</td>
</tr>
<tr>
<td><strong>Molecular Weight</strong></td>
<td>99</td>
<td>32</td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>0.74</td>
<td>0.795</td>
</tr>
<tr>
<td><strong>Lower Heating Value, MJ/kg</strong></td>
<td>42.5</td>
<td>19.7</td>
</tr>
<tr>
<td><strong>Octane Number (RON)</strong></td>
<td>100</td>
<td>108.7</td>
</tr>
<tr>
<td><strong>Cruise Range, km</strong></td>
<td>600</td>
<td>450</td>
</tr>
<tr>
<td><strong>Vehicle Exhaust Emissions, g/km</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>0.86-2.08</td>
<td>0.2-1.43</td>
</tr>
<tr>
<td>CH</td>
<td>0.08-0.19</td>
<td>0.03-0.06</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>0.2-0.43</td>
<td>0.04-0.19</td>
</tr>
<tr>
<td>1,3 Butadiene</td>
<td>0.6</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Benzene</td>
<td>4.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Aldehydes</td>
<td>2.5</td>
<td>5.8</td>
</tr>
<tr>
<td>Methanol</td>
<td>---</td>
<td>79</td>
</tr>
</tbody>
</table>
Methanol for Transportation Market

- Can replace both gasoline and diesel
- Vehicle engines prefer oxygenated fuels
  - Engines are more efficient due to less air intake - methanol has half gasoline HHV but engines require only 30% more
  - Build-in oxygen reduces emissions over entire driving cycle
- Technical issues
  - Toxicity, Poor miscibility with gasoline, Hard to startup during cool weather, Too high a vapor pressure during the hot weather, Engine gasket corrosion
- Using additives can solve the technical issues above
- Need 1,200 million tonnes/year even at 15% blending with gasoline/diesel
Other Market Potential for Methanol

- Can cheaply dehydrate to DME for replacing LPG
- Methanol provides missing link to production of coal-based petrochemicals
  - Olefins are the basic feedstocks to produce polymers and many other petrochemicals
  - Old way is to convert coal into carbide, which then reacts with water to produce olefins (acetylene) – polluting & expensive process
  - New & economic way is to convert coal-based methanol into olefins (UOP’s MTO process or Lurgi’s MTP process)
Methanol Market Size and Price

- Consumption: 32 million tonnes in 2005
- Methanol produced in NG rich regions @ $60/tonne
- Very volatile market price; causes:
  - Overbuild in NG rich regions
  - Limited market for making chemicals
- Much larger market for transportation fuel, household fuel, and petrochemicals; price should stabilize & key to gasoline/diesel price
- Price expected to stabilize @ $340/tonne, corresponding to $85/bbl gasoline/diesel (or $60/barrel crude) adjusted by HHV difference
- China consumes 7 million tonnes methanol in 2005; new production plants being built (2/3 from coal) have capacity of 10 million tonnes
DME & Olefin Market Sizes and Prices

- **DME**
  - LPG sale in 2005: 205 million tonnes; $580/tonne; $120 billion
  - DME HHV: 68% of LPG
  - No need to change burner to switch from LPG to DME
  - DME price: $400/tonne after adjusting for HHV difference from LPG

- **Olefins**
  - Ethylene sale in 2005: 133 million tonnes; $750/tonne; 100 billion
  - Propylene sale in 2005: 80 million tonnes; $800/tonne; 65 billion

Large market for methanol to grab
Barriers of Using IGCC In India and China
Characteristics of India Coals

- High ash content (35-45%)
  - Detrimental to entrained bed gasifier
  - Penalize IGCC more than PC
- High ash fusion temperature
  - Detrimental to entrained bed gasifier
  - Fluid bed gasifier is ideal, but no vendor support
- High reactivity
  - Entrained bed gasifier is overkill
  - Fluid bed gasifier is ideal, but no vendor support
- Low sulfur content (<0.5%)
  - Less environmental driving force to use IGCC

Nexant
Applications of IGCC in India

- Operated several coal gasification plants in the past
- Coal is not very ideal for IGCC
- Suited fluid bed gasifier needs development
  - Tests in US/India showed Indian coal converted well in this type of gasifier despite the high ash content
- Emission standards are not stringent in India
  - FGD is still not required for PC
- Large cost differential over PC
  - PC costs only $700/kW
- India still plans to support a 100 MW IGCC demo
  - Potential to be competitive with technical advancements
  - Environmental & GHG reduction pressures
Applications of IGCC in China

- China is leading in using coal gasification; but all for chemical production; no IGCC yet
- Emission standards are not very stringent in China
  - FGD is required for PC but not well enforced
  - Emission limits of sulfur and NOx are still higher than those in developed countries
  - Emission control on mercury, arsenic, and trace pollutants are not considered at all
- Large cost differential over PC ($700/kW)
- Power generation over built; detrimental to build IGCC

Going the direction of polygeneration
Summary
Conclusions

- IGCC currently cannot compete with PC
  - Cost of generation is 10-15% more
  - Availability is lower (75-85% vs. 90-95%)
  - PC using super-critical steam cycle catches up in efficiency

- IGCC, however, has great commercial potential
  - Ample rooms for technical advancements, performance enhancements, and cost reduction
  - More cost effective to comply with stringent emission control
  - More cost effective for carbon capture
  - Fuel flexible - can use low cost petroleum coke
  - Can co-produce transportation fuels/chemicals by polygeneration

- WB financing for IGCC projects can promote clean and carbon-free use of coal and petcoke
|-----|----------------|----------|-----------|------|------|
# Other Coal/Coke Based Gasification Plants

<table>
<thead>
<tr>
<th>Gasifier</th>
<th>Feedstock</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Texaco</strong></td>
<td>Coal</td>
<td>1,300 tpd Tennessee Eastman coal to chemicals&lt;br&gt;1,000 tpd Lunan coal to ammonia in China&lt;br&gt;1,000 tpd Ube coal to ammonia in Japan&lt;br&gt;900 tpd Hefi City coal to ammonia/urea in China</td>
</tr>
<tr>
<td>Coke</td>
<td></td>
<td>120 MW Motiva Refinery IGCC in Delaware&lt;br&gt;600 MW Citgo Refinery IGCC in Louisiana (in engineering)</td>
</tr>
<tr>
<td><strong>Shell</strong></td>
<td>Coal</td>
<td>900 tpd coal to chemicals at Yingcheng, China (2004 startup)&lt;br&gt;2,000 tpd coal for ammonia/urea at Donting, China (2004 startup)&lt;br&gt;1,200 tpd coal for chemical at Liuzhou, China (2005 startup)&lt;br&gt;2,000 tpd coal for chemical at Heibei, China (2005 startup)</td>
</tr>
<tr>
<td>Coke</td>
<td></td>
<td>2,300 tpd IGCC with H2 coproduction at Paradip, India (2005 startup)&lt;br&gt;5,000 tpd IGCC at Sardinia, Italy (2006 startup)</td>
</tr>
<tr>
<td><strong>Lurgi</strong></td>
<td>Coal</td>
<td>16,800 tpd lignite to SNG in North Dakota&lt;br&gt;100,000 tpd coal to liquid fuels and chemicals in South Africa</td>
</tr>
<tr>
<td><strong>U-Gas</strong></td>
<td>Coal</td>
<td>800 tpd Wujing trigeneration plant in Shanghai</td>
</tr>
<tr>
<td><strong>BGL</strong></td>
<td>Coal</td>
<td>540 MW IGCC in Kentucky (2007 startup)&lt;br&gt;541 MW IGCC in Ohio (2007 startup)</td>
</tr>
</tbody>
</table>