Centre for Global Energy Studies
26th Executive Retreat, Pennyhill, UK
29 – 30th September 2005

“Difficult Oil”

Dr Robert Skinner
Director

Oxford Institute for Energy Studies

www.oxfordenergy.org
Outline

• Introduction-definitions
• Resources
• Production
• Outlook
• Why/why not invest
• Market and other issues
• Summary / Propositions for discussion
Unconventional Oil & Gas: A Conceptual Framework

**Accelerating or Reversing** geological processes

→ increase H/C Ratio

**Accelerating**
- CBM
- Shale Gas
- Tight Gas
- LNG
- Shale ‘Oil’
- Coal to Liquids
- Coal
- Shale

**Conventional**
- Gas
- Oil
- Ultra-Heavy
- Bitumen
- Degradation
- Bio-Ethanol
- Bio-diesel

**Reversing**
- Stranded Gas
- D = Depressurization
- F = Fracing
- HW = Horiz. wells
- D = Depressurization
- F = Fracing
- HW = Horiz. wells

Bio-Ethanol ↔ Sugar cane, maize, wheat, sugar beet, cellulose…
Bio-diesel ↔ Vegetable oils, Jatropha bean, oil nuts…

FT = Fischer-Tropsch; R-P = Retorting/Pyrolysis;
DL = Direct Liquefaction; M = Mining;
P = Primary, SI = Steam Injection; FF = Fire-flood
Estimated Production of Unconventional Liquids (04)

- Biofuels* (2005)
- EOR (Steam)
  - Others (13 - 19°API)
  - Canada (10 - 13°API)
  - Indonesia (22°API)
  - China (11 - 24°API)
  - Venezuela (8.5 - 15°API)
  - California (11 - 14°API)

- Ultra heavy crude (Orinoco, Venezuela)
- Oil from Oil Sands (Bitumen: Canada)
- Oil from Coal
- Shale Oil

* Gasoline equivalent

[Not included in other estimates here]
Difficult Oil

<table>
<thead>
<tr>
<th>Production</th>
<th>Yield (bbl / t)</th>
<th>Resource Gbbl (URR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTL</td>
<td>1 bbl per 10,000 cf gas</td>
<td>~300 ?</td>
</tr>
<tr>
<td>Biofuels (2005)</td>
<td>2.7 Corn → Ethanol, 2.9 Rape Seed → biodiesel, 3.1 Jatropha seeds “”</td>
<td>--</td>
</tr>
<tr>
<td>Ultra heavy crude (Orinoco, Venezuela)</td>
<td>?</td>
<td>1,200 to 1,900 (120)</td>
</tr>
<tr>
<td>Oil from Oil Sands (Bitumen: Canada)</td>
<td>0.5</td>
<td>1,699 to 315 (174)</td>
</tr>
<tr>
<td>Oil from Coal</td>
<td>1.4-3.7</td>
<td>?</td>
</tr>
<tr>
<td>Shale Oil</td>
<td>0.4-1.4</td>
<td>2,100 (US)</td>
</tr>
</tbody>
</table>
Oil from Coal

- Liquid by-product of coke production (1840’s)
- Original feedstock (aromatics) for petrochemical industry
- UK and Germany (WWII), and Apartheid South Africa
- Direct and Indirect processes (> 30 schemes developed)
- China looking at large development (> 1 mb/d)
- Environmental penalties (7 – 10X CO₂ vs conv crude)
- Energy penalties (55% to 70% energy conversion)
- Potential long term bridge to Hydrogen future with sequestration of Carbon but significant replacement of conventional crude would require massive increase in coal production
Oil from Shale

- Very long history
- Massive resource
- Requires a lot of energy and water
- Wastes / Tailings
- Brazil project
- Green River Shales; Largest resource in the world in one of the driest parts of the US: Shell in situ electric heating pilot.

- Has always been ‘tomorrow’s energy source’.
- New US Energy Policy Act (Sec 369) promotes ‘re-launch’
Biofuels

- Mostly Ethanol (Brazil, USA); EU favors Biodiesel
- >30 countries have launched Biofuels programs.
- Mandates and targets in US and EU
- EU farmers oppose cellulose-based Biofuels
- US promoters oppose imported sugar-based ethanol

- Essentially an agro-business / rural subsidy business
- Great political appeal (jobs, ‘self-supply’, environment)
- Debate whether net environmental and energy benefits
- Market problems with blending
- Farmers’ opportunity to integrate downstream
- But volumes & trade are growing very fast
GTL: What & Why?

- 70-year old technology (Fischer-Tropsch), with new innovations in design and catalysts → very high quality suite of products (Diesel, Paraffinic Naphtha → Petrochemicals, plus Lubricants and Waxes)

\[
\text{CH}_4 + \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2 \xrightarrow{(\text{Fe, Co})} -n(\text{CH}_2)- + \text{H}_2\text{O}
\]

- Monetize ‘stranded’ gas resources
- Diversification (for producer & consumer)
- Environmental (X flaring & product specs)
- Corporate
  - Monetize R&D and I.P. investments
  - Materiality & baseload production
  - Reserves booking of feedstock gas (boe) and Associated Liquids (C_{5+})
  - Product specs compliance
  - Market dominance in specialty products
GTL Project List is long…

<table>
<thead>
<tr>
<th>Project/Company/Country</th>
<th>Existing / Under construction (b/d)</th>
<th>Announced or Under Study (b/d) start year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mossgas, PetroSA, South Africa Bintulu, Shell, Malaysia Pilots (9)</td>
<td>23,000 14,700 2,360</td>
<td></td>
</tr>
<tr>
<td>ORYX, Sasol/QP, Qatar Sasol/QP, Qatar Shell/QP, Qatar ‘Pearl’ Chevron/Sasol/QP Exxon Mobil/QP, Qatar Conoco/Phillips/QP, Qatar Marathon/QP, Qatar</td>
<td>34,000 (06)</td>
<td>65,000 (09) 140,000* (2 X 70,000) (09, 11) 130,000 (10+) 150,000* (2 X 75,000) (11) 160,000* (2 X 80,000) 120,000* (2X 60,000)</td>
</tr>
<tr>
<td>Shell/NPC, Iran Statoil/NPC, Iran Sasol/NIIOC, Iran Shell, Pertamina, Indonesia Sasol/Chemvron/NNPC, Nigeria Sasol/Chemvron, Australia EGPC/Shell, Egypt Rentech, Bolivia Brazil-Syntroleum/Petrobras, Reema Int/Syntroleum, Trinidad PDVSA/Sasol Sasol/PetroTrin, Trinidad Gazprom/Yukos/Syntroleum</td>
<td>34,000 (06/07)</td>
<td>75,000 20,000* 140,000 (2 X 70,000) 75,000 34,000 – 200,000 75,000 10,000* ? 10,000 34,000 30,000 120,000 (12 X 10,000)</td>
</tr>
</tbody>
</table>

These projects =1,465 kb/d Others identify >1,900 kb/d

* Reported FEED
GTL Slowing down?

- Qatar announces slow-down in development: “reservoir”? ‘overheat’? or opportunity cost versus LNG?

- Countries with large reserves re-assessing LNG prospects given natural gas supply squeeze in North America

- Countries with small ‘stranded’ gas reserves/small fields still candidates for GTL (Trinidad?); want industrial diversification built on other, existing gas infrastructure/industry

- EPC supply, skills; specialty steel ‘shortage’; large vessel suppliers very constrained

- COSTS are the key challenge for all GTL schemes. Not the time to assign these projects to the ‘D-Team’ → reputation risk;

- Banks prefer LNG: market expanding: no major potential surprises.

- GTL scale-up issues.
GTL products Market

- Existing infrastructure/vehicle stock
- Diesel: high quality (S, Cetane, PM, HCs, CO), anticipates new specs—marketing tool
- Naphtha → good ethylene feedstock
- Kerosene: better to reduce output
- Specialty lubes and waxes face potential ‘over-supply’. Operators must either discount, blend with conventional lube stocks or crack to shift output to lighter grades.
- ‘Degrading’ of ultra-high quality products
- Remember: it’s transport service (CNG?)
Ultra-Heavy Crude (Orinoco) & Bitumen (Athabasca Oil Sands)

Extra Heavy Oil in Place
1,360 Gbbls
Recoverable 120 Gbbls
(PDVSA)

Initial Bitumen in Place
1,699 Gbbls
Remaining Established 174 Gbbls
Ultimate Potential Recoverable
315 Gbbls
(AEUB, 2005)
Heavy Oil Categories

API Gravity

Downhole Viscosity (Cpo)

C Class: Bitumen

B Class: Extra Heavy

A Class: Medium Heavy

After Kupcic, 2003
Alberta Oil Sands Projected Supply

1000 b/d

Estimated (risked) output adjusted from announced schedules

Herd instinct?

* Except OPTI/Nexen, which uses SAGD integrated with upgrader

Source: OIES
Reasons firms give for investing in Oil Sands

- No or little geologic risk; materiality
- Long term predictable growth versus conventional decline
- Technology up-side:
  - Can unlock value through technology-driven cost reductions and increased reserves.
- With high % WI: can control pace.
- Practice makes perfect—once in it, keep doing it, but do it better.
- Lower risk profile, good for valuations
  - Manufacturing or ‘annuity’ profile (repeatable)
  - Balances conventional E&P profile
  - Balances offshore/foreign, riskier ventures
  - Less single event risk
  - Less cash flow volatility
  - Financial & equity markets like it

- Economics are robust:
  - Netbacks high; low F&D, long RLI
  - Amortize costs over large reserves
  - Minimal sustaining capital
  - Attractive fiscal regime, promotes expansion
  - IRR>industry WACC @ 9%
But not all ‘rosy’ picture

- **Project execution**: large-scale, simultaneous projects in an northern environment (logistics, materials, equipment and skilled manpower) \(\rightarrow\) major cost overruns

- High CAPEX projects limit scope for investments elsewhere

- Operational Risks: asset reliability in northern environment

- **Natural gas supply** (steam, power & hydrogen) unsustainable

- **Markets**: market saturation (need coking for Heavy Sour & cracking capacity for SCO); supply upsets, new market access

- **Environmental issues** and performance (\(\text{CO}_2\) vs Recovery)

- ‘Rent debate’ starting (again)

- **Financing**: Business cycle; interest and exchange rates; SEC
Oil Sands Production & Supply

2.5 mb/d                        Total Canadian Production (ex NGLs)                        ~ 4 mb/d

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Heavy Supply</th>
<th>Incremental Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2002</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2003</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2004</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2005</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2006</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2007</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2008</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2009</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2010</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2011</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2012</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2013</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2014</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
<tr>
<td>2015</td>
<td>~ 145 kb/d/year</td>
<td>~ 145 kb/d/year</td>
</tr>
</tbody>
</table>

Source: AEUB, CAPP, OIES
Oil Sands will be hard-pressed to fill Growing North American Supply – Demand Gap

Annual Oil Sands Supply Additions (CAPP)

Annual change in gap (BP)

N.A. Oil Consumption

N.A. Oil Production

Avg 1990 - 2004

US DOE/EIA 2005 Outlook

Projected N.A. Gap

Projected (OIES)

Source: OIES, BP (2005), CAPP, US DOE/EIA
Technology Challenges & Options
Natural Gas, Water Use, Emissions & Diluent

**Mining** (90% recovery already)
- At-face mobile, continuous mining & extraction
- Improve energy efficiency in water separation
- Tailings, water use, land recovery, resource conservation

**Upgrading**
- Better quality SCO
- Field upgrading to improve bitumen quality
- Reduce upstream CO2 emissions (15 to 30% of Life Cycle Emissions)

**In Situ** (40 – 70% recovery)
- Steam fuel (bitumen, asphaltenes, coal, POX …nuclear?)
- Reduce Steam Oil Ratio; improve water re-cycle, reduce use.
- Better down hole pumps
- Thief Zones; reservoir modelling and monitoring
- In situ partial upgrading (THAI™, VAPEX, catalysts, …microbes?)
Difficult Oil: Projects

Current & Proposed Projects

- **GTL**: 1.9
- **Biofuels (2005)**: 0.7 *
- **Ultra heavy crude (Orinoco, Venezuela)**: 2.1
- **Oil from Oil Sands (Bitumen: Canada)**: 4.1
- **Oil from Coal**: 1.35

**TOTAL ~ 10.15 mb/d**

*Gasoline Equivalent
Estimated CAPEX ($000/b/d)

- Ethanol: 35 – 56*
- Biodiesel: 13 – 15*
- GTL: 25+ (target 20)
- Ultra heavy crude**: 27 – 30
- Oil Sands**: 30 – 40
- Coal to Liquids: 40+?
- Oil from shale: ?

* Plant only, gasoline equivalent (from recently announced plants Australia, EU, USA)
** For integrated project yielding fully upgraded synthetic crude
Unconventional Oil: Some Propositions

• Supply will grow—especially from oil sands and Biofuels; GTL will slow; USA political push for shale & coal, but…?

• Orinoco: most economic, least discussed, likely to slow down until perceived political risk reduced

• Upgrading of heavy crudes and bitumen will increase at source to capture value (Alberta, Brazil, Saudi Arabia, Venezuela).

• Costs increasing but most except shale and coal will continue @ >$30/bbl.

• Unlikely to exceed 10% of world supply before 2020.

• Market problems for specialty streams: degrade or dilute high value products with very high energy input

• North Field gas → *steam in Athabasca* and *corn ethanol in South Dakota*?
  “It’s a funny old world.” Margaret Thatcher, 1990

• Could a ‘Type SCO’ one day emerge as a reference crude?