Deep Basin Tight Gas: Resource Characterization, Assessment and Future Supply

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Deep Basin Tight Gas

Western Canada Tight Gas Resource Characterization Project

Natural Resources Canada - GSC

Devon Canada Corporation
Husky Oil Operations Ltd.
Imperial Oil Limited
Petrel Robertson Consulting Ltd.
Talisman Energy Inc.
TransCanada Pipelines Limited

NEB, CGPC, BCMEMPR, EUB, Sask IR, ARI, USGS, EIA
Resource Models Differ

**CONVENTIONAL**
1. Discrete gas pools in ocean of water
2. Only high quality reservoir accumulates gas in place
3. Discovery is uncertain, recovery is certain
4. Discovery process is efficient
5. R&D to increase success
6. Remaining resource, in small undiscovered pools, is small
7. Official view of WCSB remaining resources

**UNCONVENTIONAL**
1. Pervasive gas saturated accumulations
2. Very large gas in place in reservoir of all qualities
3. Discovery is certain, recovery is uncertain
4. Recovery is inefficient but improves with technology
5. R&D to improve recovery and characterization
6. Remaining resource in lower quality reservoirs is large
7. US and industry view of WCSB remaining resources

"Glass is mostly empty"  
"Glass is mostly full"

Outline

- Deep Basin plays
- Characterization
- Resource Estimates
- Supply Modelling
- Conclusions
Deep Basin tight gas
Cumulative Raw Gas per Township, Bcf
Wells Onstream to 2005, Production to Feb 2007

Western Canada Tight Gas

Jean Marie
Cum production: 1.3 tcf (raw)
4.5% of rate additions 03-05
2.5% of production 03-05

Milk River – Med Hat – 2WS
Cum production: 14 tcf (raw)
11% of rate additions 03-05
10% of production 03-05

Deep Basin tight gas
Cum production: 17 tcf (raw)
21.5% of rate additions 03-05
15% of production 03-05

Tight Gas Regions
Cumulative Gas per Township, Bcf
November 2007

Pervasive gas downdip
Water saturated updip and in underlying and overlying formations
Transition zone location varies by formation
Foothills is western limit
Conventional buoyancy traps in aquifers
Tight gas sands downdip with sweet spots
8 stratigraphic intervals, 13 plays evaluated
Stacked plays
Thickness is typical only of northern Deep Basin
Stippled zones are not continuous reservoir and only about 1/3 sandstone
Drilling targeted to underlying Triassic and Paleozoic plays

Modified after Masters 1979, 1984
Deep Basin Tight Gas

- Play definitions
- CGPC resource plays
- Anomalous pressure
- Very large play areas
- Play stacking

Deep Basin Play Outlines
Maximum extent ~ 40,000 sq. miles

Maturity Varies by Play

- Evaluated area varies from 18% to 67%
- Uncertainty increases for less mature plays
- Most wells have modern log suites
- Many wells drilled since the Deep Basin trap concept was described in 1970s

- Accelerating activity, particularly in northern plays, since 1992
- Drilled area of Cadomin play has tripled in last 10 years

Increasing activity targeted to Deep Basin tight gas
Gas Well Connections

- Total annual connections growing rapidly
- 28% growth rate from 2002 to 2006
- Cadomin, stacked plays and Cardium plays lead connection growth
- Declining connections in some plays: Cadotte and Bow Island

- Stacked play wells: segregated production from different plays or commingled production from two or more plays
- Stacked play wells average 13% of total connections

63% of all Deep Basin connections since 1998

Gas Production

- Total production grew by over 1 Bcf/d since 1998
- 6% growth rate from 1998 to 2006
- Cadomin, Multiplay and Cardium plays lead production growth
- Declining production in some plays: Cadotte, Upper Mannville South and Bow Island

- Multiplay: commingled production from two or more plays where the primary producing zone cannot be distinguished
- Commingling regulations will result in far more Multiplay producers in future

2005 Deep Basin production: 1 Tcf per year
**Estimate EUR per Well**

EUR: Estimated Ultimate Recovery
- Calculate EUR using normalized production profile by play, current rate, producing time and cumulative production
- Normalized production profiles vary in shape between plays
- All profiles are hyperbolic with high initial decline rates

**EUR Connected**

- EUR connected growing
- Growth rate not as rapid as wells connected
- Cadomin, Multiplay and Cardium plays lead EUR connected growth
- Declining EUR connected in some plays: Cadotte, Upper Mannville South and Bow Island
- Multiplay: commingled production from two or more plays where the primary producing zone cannot be distinguished with publically available data
- Commingling regulations will result in far more Multiplay producers in future

**Almost 22 Tcf connected by 2005 in Deep Basin plays**

**Deep Basin EUR connected exceeds production**
Deep Basin Tight Gas November 2007

Success Rate

- Historical total success rates for individual plays are low relative to US tight gas plays
- Annual success rates have been fairly consistent through time
- Recent trend in the Cadomin is exception
- Success in any Deep Basin play: 35%

Success by Deep Basin Play

- Success: Section where at least one well drilled to the play has an EUR greater than a minimum EUR (commonly 0.25 Bcf)
- Multiplay success sections have been allocated to pure plays

Low success rates: discovery is uncertain!

Resource Estimation Methods

- Discovery process models: “Law of diminishing returns”
  - Discrete pools in play where discovery history exists - CGPC
- GIP: “Dream the Big Dream”
  - Subsurface volumetric study from petrophysics and mapping
  - John Master’s 1984 estimate of 1500 Tcf GIP for Mannville in the Deep Basin trap!
- Cellular methods:
  - Extrapolate resources to undrilled areas based on well recovery, success rate and well spacing from drilled and evaluated areas
  - US EIA resource estimates for unconventional gas from USGS and Advanced Resources International (ARI)

Resources = (Area * Success / Spacing) * EUR/well

- Area: Undeveloped area
- Success: % of Undeveloped area EUR > cutoff
- Spacing: Average drainage area of wells
- EUR/well: Average EUR for successful well
EUR per Well

- EUR per well decreased rapidly – from few high EUR wells to many lower EUR wells connected recently
- Decrease since 2000 has been relatively low – we believe improved technology is offsetting the decline trend
- Stacked play wells have slightly higher EUR per well than average

Trend driven by price and pursuit of marginal EUR

Well Spacing

- Most plays are currently drilled at 640 acres with minor downspacing
- Exceptions are Cardium, Dunvegan, Lower Mannville South and Cadomin
- Expected Recovery and Advanced Recovery scenarios envision incremental decreases in well spacing

Contrasts with US tight gas plays where well spacing is 26 to 160 acres
Are Deep Basin operators satisfied with current recovery of GIP?
Resource Estimation Scenarios

- Continuing Trends scenario
  - Undeveloped area will experience the historical success rate and well spacing but a lower mean EUR than recent drills

- Expected Recovery scenario
  - Incremental improvements: success rate is higher and well spacing is reduced resulting in more successful wells

- Advanced Recovery scenario
  - Significant improvements: success rate is higher, particularly for immature plays, and the trend to downspacing is extended

- EUR per well remains constant in all scenarios
  - Technology identifies and recovers same EUR from progressively lower quality reservoir

- Success rate increases and drainage area decreases
  - Lower quality reservoir will be recognized and completed as successfully productive
  - Reservoir characterization identifies downspacing opportunities

Deep Basin Resource Estimates

- 22 Tcf resource developed to 2005

- Under the Expected Recovery scenario: 23 Tcf undeveloped resource, to be connected from 2006

- Cadomin (6.5 Tcf) and Gething (3.8 Tcf) largest portions of undeveloped resource

- Continuing Trends scenario estimate: 16 Tcf

- Advanced Recovery scenario estimate: 30 Tcf

45 Tcf ultimate resource
Comparison to CGPC

- Forward Energy Expected Recovery estimate is 20.3 Tcf vs 12.6 Tcf for CGPC
- Cadomin and Gething >90% of increase
- Most Cadomin reserves reporting post-dates the year-end 2003 reserves CGPC
- CGPC estimate based on 2003 year end reserves was factored to non-associated gas and adjusted by EUR connected 2004 to 2005

>60% increase in undeveloped resource

Gas Supply

- 10,000 wells onstream produced 14 Tcf to 2005; remaining EUR of 7 Tcf produced by 2030
- At a medium development pace, Deep Basin peak output (2.9 Bcfd) reached in 2006; long term rate stabilizes near 2.8 Bcfd
- Rate of supply constrained by finite volume of undeveloped resource (23 Tcf)

- With Advanced Recovery, technological advances improve success rates, increase down spacing and maintain EUR/well metrics over the longer term
- Most Advanced Recovery volume (7 Tcf) developed and produced after 2030

Expected Recovery will not sustain Deep Basin rates
### Tight Gas Play Comparison

**Deep Basin and US Rocky Mountain region**

<table>
<thead>
<tr>
<th></th>
<th>Deep Basin</th>
<th>US Rockies Tight Gas</th>
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<tbody>
<tr>
<td><strong>Plays</strong></td>
<td>13</td>
<td>13</td>
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<tr>
<td><strong>Production, 2005</strong></td>
<td>2.7 Bcf/d</td>
<td>5.6 Bcf/d</td>
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<tr>
<td><strong>Play areas</strong></td>
<td>Very large</td>
<td>Small</td>
</tr>
<tr>
<td></td>
<td>3,500-21,500 sq miles</td>
<td>1,000-6,500 sq miles</td>
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<tr>
<td><strong>Play success rate</strong></td>
<td>Low</td>
<td>High</td>
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<td></td>
<td>5%-25%</td>
<td>73% to 96%</td>
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<tr>
<td><strong>Well Spacing, future</strong></td>
<td>220 - 500 acres</td>
<td>26 -160 acres</td>
</tr>
<tr>
<td><strong>EUR per section, Bcf</strong></td>
<td>Modest 0.5 to 3.4 Bcf</td>
<td>Large 2.2 – 50 Bcf</td>
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<tr>
<td><strong>Undeveloped Resources</strong></td>
<td>22.9 Tcf</td>
<td>67.1 Tcf</td>
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<tr>
<td><strong>Reservoir interval</strong></td>
<td>10's of feet</td>
<td>100's of feet</td>
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<tr>
<td><strong>Play area % drilled</strong></td>
<td>Higher %</td>
<td>Lower %</td>
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<tr>
<td><strong>Sand/shale ratio</strong></td>
<td>Low</td>
<td>High</td>
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**Sources:** Forward Energy, EIA AEO2007 supply model inputs

### Conclusions

**Deep Basin plays differ from Unconventional model**
- Low success rates, singly or stacked
  - Discovery remains uncertain and requires management
- EUR per well has been decreasing
  - Rather than recovery per well increasing with advancing technology, recent high prices made lower reserve prospects economic
- Low frequency of downspacing
  - Operators appear satisfied current spacing will drain GIP
- Coadomin, Cardium and Lower Mannville South plays appear more similar to Unconventional model

**Undeveloped Resources**
- Resource estimates range from 16 Tcf to 30 Tcf

**Future Supply**
- Expected Recovery of 23 Tcf will be connected, reach peak rate before 2020 and will be mostly consumed by 2030
- Increased supply from an Advanced Recovery scenario will require focused industry and government-supported R&D into technology to reduce risk and increase recovery
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