Overall Perspectives

• 1970s & 1990s “redux” with regard to perceptions about reliability, deliverability
  – Similar policy/regulatory disconnects are happening now

• Even without GHG policy, gas “push” is inevitable
  – With GHG caps, low carbon technologies are immature, timing of deployment and cost highly uncertain
  – Even without caps, strategic opposition to electric power transmission hinders both coal and renewables

• Oil and gas tax policies impact development
  – IDCs are particular challenge for continued drilling and exploitation
Conflicting Policy Views Persist

*Even with storage at historic highs...*

<table>
<thead>
<tr>
<th>“Gas Short”</th>
<th>“Gas Long”</th>
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<tbody>
<tr>
<td>- Prevailing political sentiment (state regulators)</td>
<td>- Prevailing industry sentiment</td>
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<tr>
<td>- Unconventional plays are unsustainable</td>
<td>- Unconventional plays are sustainable</td>
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<tr>
<td>- Global competition for LNG disadvantages US</td>
<td>- LNG will swing to US for storage, peak shaving</td>
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<tr>
<td>- Persistent high and “volatile” prices</td>
<td>- Generally lower price deck but with price spikes</td>
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“Gas Short” Implications

• Undermines critical assumption that gas will be available for balancing
  – Renewables dispatch sensitivity
• Limits gas to incremental use
• Used to block progress on key upstream and midstream initiatives
  – OCS and other moratoria/restrictions
  – ROW for midstream
“Gas Long” Implications

- Gas can expand beyond “bridge fuel” assumptions
  - Persistent oil:gas price premium can support mixed end uses
  - Search for non-weather sensitive base load and cohesive commercial framework (policy/regulatory/market)
- Builds customer expectations regarding pricing and price risks
  - Search for strategies to dampen volatility, moderate prices, preserve margins for producers
- Adds to pressure on producers for value
- Discourages incremental LNG development near load centers
Impact of Technology – Deferring Declines

- Oil discovered in Titusville, Pennsylvania, 1859; natural gas replaces town gas, 1870s
- Oil discovered at Spindletop (Texas), 1901
- Oil discovered in Titusville, Pennsylvania, 1859; natural gas replaces town gas, 1870s
- Advances in drilling, early seismic, shallow offshore E&P

**Porosity, permeability:**

<table>
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<tr>
<th>IT Pathway:</th>
<th>Conventional</th>
<th>Unconventional</th>
<th>“Nano”</th>
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<td>Mainframes</td>
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**Cumulative U.S. Oil & Gas Production, 1936-2007**

BBOE (Includes Alaska)

- 3-d seismic, horizontal drilling, measurement while drilling, offshore below 1,000ft
- Pipeline trenching and welding, compression, pressure control, metering; national grid develops
- Directional drilling, offshore below 250ft water depth
- Long-line pipeline transmission
- Advances in drilling, early seismic, shallow offshore E&P

**Oil & Gas Technology Pathway**

- Arctic?
- Hydrates?
- Offshore below 10,000ft
- 4-d seismic, offshore below 5,000ft

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Major US shale basins.

- Niobrara
- Green River
- Baxter
- Mancos
- McClure
- Monterey
- Cane Creek
- Hovenweep
- Lewis and Mancos 97 tcf
- Pierre
- Palo Duro
- Barnett and Woodford
- Pearsall
- Barnett 25–252 tcf
- Haynesville/Bossier Woodford
- Fayetteville
- Caney and Woodford
- New Albany 86–160 tcf
- Antrim 35–76 tcf
- Utica
- Marcellus
- Huron
- Chattanooga
- Floyd and Conasauga/Neal
- Horton Bluff

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Barnett Shale

Estimated ultimate recoveries per well:
“Sweet Spot”: 3.0 bcf plus
Second tier: 2.5 – 3.0 bcf
Third tier: 1.75 – 2.5 Bcf
Fourth tier: 1.25 – 1.5 bcf
Fifth tier: 0.5 – 1.25 bcf
Basin margin: 0.5 bcf
Barnett Shale Experience

• Water use for “fracing” and other Barnett Shale development is less than 1% of total water use in affected counties
  – Water use has been growing, but rate of use in future may be lower with technology improvement and recycling
  – Operators are actively testing recycling to manage water demand and produced water

• NETL Produced Water MIS
  http://www.netl.doe.gov/technologies/PWMIS/
Shale Gas Pores

Areas of higher carbon content

SEM of ion-cut surface

SEM from Reed and Loucks

Blakely Well, 7,111′
New “Nanodarcy” Universe of Technology

- Detection and advanced stimulation
- Slow decline curves
- Reduce drilling (fewer rigs, lower costs)
- Manage water disposal issues