The Future Role of Natural Gas in the U.S.

U.T. Energy Symposium

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U.S. Natural Gas Supply and Demand Outlook
U.S. Natural Gas Reserves and Resources

Sharp increase in shale gas resource estimates in recent years

“Proven” = SEC proven reserves; all other categories shown are technically recoverable resources
DOE = Data from U.S. Department of Energy, Energy Information Agency “Annual Energy Outlook”; data are as of January 1 of year indicated; 2007 data published in 2009 report
Tight Gas is included in Conventional Resource estimates for all years
Gas Production Outlook from Key North American Shale Gas Plays

Large increase in NA shale gas production through 2020

Source: Wood Mackenzie
Cost of North American Resource Plays

Cost of service ($/MMbtu)\(^1\)

Sources: Morgan Stanley
1 Henry Hub basis required for 10% IRR.
2 Value based conversion of $72/BBL = $6/MMbtu due to high liquids yield.
Unconventional natural gas will dominate new U.S. supply

Source: COP

* Observed decline rate, including reinvestment
U.S. DOE Forecasts of Required U.S. LNG Imports

The U.S. is projected to be more self-sufficient

Source: U.S. Department of Energy, EIA Annual Energy Outlooks
Crude-to-Gas Price Ratio

Sources: Futures is NYMEX settle on 9/7/2011; DOE is 2011 Annual Energy Outlook
* WTI ($/bbl) divided by Henry Hub ($/mmbtu)

Some disconnect between U.S. gas and global oil prices likely to remain
Changing Electricity Generation Mix

% of Electricity Generation

Other renewables
Forecast

- Wind
- Nuclear
- Hydro
- Natural Gas
- Petroleum
- Coal

Natural gas will gain share in electricity generation

Source: EIA (history), COP (forecast)

After two decades of leading growth, natural gas has second largest capacity growth after renewables
U.S. Coal Fleet: Capacity By Age of Plant

- Average Age = 36 years
- 71 GW > 45 years
- 31 GW > 40 years, small* & inefficient**

Source: Ventyx Velocity Suite

*Less than 300 MW
** Heat rate > 10,000 Btu/KWh

Between 30 and 70 GW (10-20% of coal fleet) could be shuttered due to more stringent environmental regulations
Role of Gas in U.S. Supply Mix
Reasons Why Natural Gas Should Play A Larger Role in the U.S. Fuel Mix

- **Energy Security**
  - Abundance & diversity of supplies
  - Increased storage and pipeline capacity
  - LNG deliverability

- **Affordability**
  - Low cost of shale gas production in North America
  - Attractive economics in gas-fired power plants

- **Attractive Environmental Properties**
  - CO₂ emissions reduction
  - Clean air (little or no NOX, SOX, VOCs, mercury)
  - Relatively small land use and water footprint
  - Enables use of renewable power sources
  - No solid waste (fuel rods, ash)

Fuel choice will be driven by government policy.
Top Ten Natural Gas Producing Nations (2010)

The U.S. was the largest producer of gas in 2010

Source: BP Statistical Review 2011
U.S. DOE Forecasts of Henry Hub Natural Gas Prices

Natural Gas Price Volatility

- **Short-term price volatility moderated by:**
  - Increased natural gas storage in the U.S.
  - Increased pipeline capacity in the U.S.
  - 18 bcfd of LNG deliverability (~25% of U.S. gas demand)
  - Production growth onshore and spread throughout the U.S., which reduces supply disruptions from hurricanes

- **Long-term upside U.S. gas price risk moderated by enormous supply potential**
  - Large low-cost unconventional gas resources in U.S. & Canada
  - Arctic gas potential (ANS gas, Mackenzie Delta in Canada)
  - Surplus global LNG capacity with ability to deliver to U.S.
  - Unconventional gas revolution in the rest of the world

Price volatility will likely be moderated and it can be managed with market tools if regulators allow it
Full-Cycle Costs of Building New Power Plants

Cents/KWh

Levelized Cost of Power

- **Capital**
- **Fuel & Operating**

- NGCC w/ $7/mcf
- Coal
- NGCC w/ CCS
- Wind
- Geothermal
- Nuclear
- Coal w/ CCS
- Solar Thermal
- Solar PV

**Attractive economics of combined cycle gas-fired power plants**

Source: DOE AEO 2011 Assumptions for overnight capital costs
Assumes 10% IRR for all technologies
Renewable sources & nuclear include a federal tax credit
**Water Intensity for Various Power Generation Technologies**

<table>
<thead>
<tr>
<th>Gallons / MWh</th>
<th>Gas-Fired Combined Cycle</th>
<th>Combined Cycle</th>
<th>Coal Thermal</th>
<th>Nuclear</th>
<th>Solar Trough</th>
<th>Geothermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Cycle*</td>
<td>Gallons / MWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Use**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Production</td>
<td></td>
<td></td>
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</tbody>
</table>

Gas-fired combined cycle power plants use much less water than thermal power plants with only a small contribution from gas production.

Source: U.S. Department of Energy, “Energy Demands on Water Resources”, December 2006; Chesapeake for shale gas water use

* Assumes closed loop cooling tower

**Other use includes water for other process uses such as emissions treatment, facilities.
### Acreage Requirements for Electricity Production

To produce the fuel and generate enough electricity to serve 1,000 households for one year:

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>0.3</td>
</tr>
<tr>
<td>Coal</td>
<td>0.4</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.8</td>
</tr>
<tr>
<td>Nuclear</td>
<td>1.2</td>
</tr>
<tr>
<td>Wind</td>
<td>6</td>
</tr>
<tr>
<td>Solar</td>
<td>6</td>
</tr>
</tbody>
</table>

Nuclear has the smallest footprint of any energy source.

*Source: R.W. Beck and Black and Veatch for NGSA*
### Pollutant Emissions From Generating Electricity

<table>
<thead>
<tr>
<th></th>
<th>Wood</th>
<th>Coal</th>
<th>Natural Gas</th>
<th>Nuclear &amp; Renewables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SO₂</strong></td>
<td>2.8</td>
<td>5.0</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>NOX</strong></td>
<td>28.0</td>
<td>3.4</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>PM</strong></td>
<td>2.7</td>
<td>0.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>VOC</strong></td>
<td>5.6</td>
<td>0.2</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

- **Tons per year per thousand households**

**Source:** R.W. Beck for NGSA

*Natural gas is clean burning*
Potential for Fuel-Switching from Coal to Natural Gas* In Existing U.S. Power Plants**

Coal-to-gas fuel-switching in existing power plants can reduce CO₂ emissions relatively quickly

* Combined cycle only

**Maximum potential - limited by transmission grid, gas pipeline & storage capacity, flexibility of power system operators, proximity of gas to coal plants, etc.

Cost of CO₂ Avoided From Switching Away from Existing Coal-Fired Power

Chart represents the cost of CO₂ avoided by switching from existing coal power to selected source

Source: DOE Cost estimates AEO 2011
GHG Emissions from Natural Gas

- Cornell University study indicated that natural gas produced from shale has more GHG emissions than coal

- Study had biased and unjustified assumptions
  - Ignored the efficiency of gas-fired combined cycle power plants
  - High fugitive emission data for shale gas wells
    - Ignored widespread use of 'green' completions & assumed that all flowback emissions vented when 50-to-90% are flared.
  - Use of 20 vs. 100-year time horizon to value warming potential
    - Disadvantages gas as CO₂ remains in the atmosphere for thousands of years, while methane has a shorter life.
  - Use of ‘new’ Global Warming Potential values for gas to capture interaction with other chemicals in the atmosphere
    - Controversial and inconsistent with IPCC
  - Undercounts fugitive emissions from coal mining

- With more realistic assumptions for comparing coal and gas in power generation, natural gas is found to emit at least 50% less GHG than coal.
Renewable Electricity Standard Will Reduce Gas-Fired Power Generation

DOE Analysis of the Impact of an RES on U.S. Natural Gas-Fired Power Generation

Implications for CO₂ Emissions Reduction

- Limited reduction in CO₂ emissions to the extent that backs out low carbon natural gas vs. coal
- Emissions trading or carbon pricing are more cost effective ways of reducing CO₂ emissions

An RES is not the most effective way to reduce CO₂ emissions

Source: U.S. Department of Energy, EIA Analysis of RES, April 2009
Growth in renewable power could back out demand for natural gas.
Will Renewable Power Lower CO$_2$ Emissions?
Impact of Intermittency

Heat rates:
- Existing coal – 11,000 btu/kwh
- SCNG – 10,930 btu/kwh
- CCNG – 7,100 btu/kwh

Source: COP
Importance of Natural Gas to the U.S. Economy

- **Employment**
  - Nearly 3 million Americans are employed in and supported by the natural gas industry
  - An additional 1.1 million jobs could be created by 2020 in the U.S. with policies that encourage the development of new and existing oil and gas resources

- **Economy**
  - Natural gas development added nearly $400 billion to the U.S. economy in 2008

- **Government Revenues**
  - Natural gas companies contributed over $4.4 billion per year on average in gas royalty payments alone to the federal government between 2005 and 2010

- **Meeting Energy Needs**
  - One-third of the nation’s natural gas is consumed by American manufacturers
  - 70 million homes and businesses use gas for heat and power
Adequate Natural Gas Supply at Competitive Prices Helps Grow the U.S. Economy

- Lower gas prices have helped U.S. industry
- Chemical and fertilizer facilities are seeing increased utilization with lower gas prices
- Energy-intensive industry can be more competitive in the global market
- Additional potential demand from natural gas vehicles

Source: Wood Mackenzie
Supportive Government Policy Needed to Capture Gas Opportunity

- Positive business climate for investment
  - Realistic tax policy
  - Ensure benefits of regulation exceed cost

- Facilitate resource access
  - Do not over-regulate hydraulic fracturing
  - Limit permitting delays

- Policies that are fuel neutral
  - Avoid picking technology winner