Natural gas and America’s Energy Future
Monday, May 2, 2011; 11:00 AM – 12:15 AM

Moderator:
Harold A. Wright, Ph.D., Senior Vice President and Chief Technology Officer, Rentech

Speakers:
James Ivey, President and CEO, Milagro Exploration
Andrew Littlefair, President and CEO, Clean Energy
Tom Price, Senior Vice President, Corporate Development, Chesapeake Energy Corp.
Joanne Spalding, Managing Attorney, Sierra Club
World consumption of natural gas

Non-OECD countries will lead consumption

Historical and projected natural gas consumption from 1980 to 2030

Trillion cubic feet

Historical

Projected

Source: Energy Information Administration
Where U.S. dry gas is found

Source: EIA
Shale gas

Source: U.S. EIA and USGS
## U.S. shale gas reserves

*trillion cubic feet*

<table>
<thead>
<tr>
<th>Resource area</th>
<th>Reserve potential (TCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marcellus</td>
<td>262</td>
</tr>
<tr>
<td>Haynesville</td>
<td>251</td>
</tr>
<tr>
<td>Barnett</td>
<td>44</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>42</td>
</tr>
<tr>
<td>Antrim</td>
<td>20</td>
</tr>
<tr>
<td>New Albany</td>
<td>19</td>
</tr>
<tr>
<td>Woodford</td>
<td>11</td>
</tr>
<tr>
<td>Non-shale</td>
<td>1,051</td>
</tr>
<tr>
<td><strong>Total U.S.</strong></td>
<td><strong>1,700</strong></td>
</tr>
</tbody>
</table>

Source: EIA
U.S. natural gas supply, domestically sourced

*billion cubic feet, 2010*

- **Domestic production**: 21,571
- **LNG from Trinidad and Tobago**: 190
- **Pipeline imports**: 3,252
- **Other LNG**: 241

*Source: EIA*
Where as oil reserves concentrate in politically unstable regions

Total proved reserves (2009): 1.26 trillion barrels

- Middle East: 60%
- Former Soviet Union: 10%
- Africa: 10%
- Latin America: 10%
- North America: 6%
- Asia Pacific: 3%
- Others: 1%

Sources: BP Amocos, Milken Institute.
World natural gas reserves
by geographic region, 2009

Source: IEA
Natural gas

Cleanest of the major fossil fuels

Source: IEA
How Americans demand energy


- Electricity Generation: 40%
- Transportation: 28%
- Industrial: 21%
- Residential and Commercial: 11%

Total U.S. Electric Power Mix

- Coal: 45.9%
- Nuclear: 20.9%
- Natural Gas: 22.1%
- Hydroelectric: 7.0%
- Other: 4.2%

Sources: U.S. Energy Information Administration
Alternative energy accounts for 7% of energy used in the U.S.

Source: Energy Information Administration.
Natural gas drives heat and electricity

Natural Gas Use by Sector

- Electricity Generation: 29%
- Transportation: 3%
- Industrial: 34%
- Residential and Commercial: 34%

Petroleum Use by Sector

- Electricity Generation: 1%
- Residential and Commercial: 5%
- Industrial: 23%
- Transportation: 71%

Sources: U.S. Energy Information Administration
The Pickens plan, circa 1938

Divert compressed natural gas from power plants to vehicles.

Fuel demands of transportation

6.5 million heavy duty trucks in U.S. fleet
  • avg. 200,000 miles per year
  • avg. 7.5 miles per gallon
2.3 million barrels of oil per day

250 million passenger cars in U.S. fleet
  • avg. 10,000 miles per year
  • avg. 20 miles per gallon
8.7 million barrels of oil per day—(cars, SUVs, & light trucks)

Source: EIA, NRDC
At the 2009 U.S. production rate, about 20 TCF per year, U.S. natural gas resource estimates could supply U.S. demand for 85 years.
U.S. energy production by fuel

Source: EIA
CNG and LNG are a growing part of U.S. alternative fuel consumption although total U.S. alternative fuel consumption is still a very small piece of the pie.

Source: EIA
Independent oil and gas producers

- Are upstream-focused small businesses, averaging fewer than 20 employees
- Drill 90% of US oil and gas wells
- Produce 80% of US natural gas and 65% of US crude oil
- Hold 90% of the leases in the Gulf of Mexico
- Prior to credit crunch, invested 150% of cash flow back into US oil and gas development
- Will bear the brunt of proposed Obama Administration budget proposals
  - Repeal the (1913) law for expensing of Intangible Drilling Cost (IDC) will reduce domestic drilling by 20-40%
  - Repeal of Percentage Depletion (1926) law will jeopardize marginal well production – 20% of US oil and 12% of US gas
  - Repeal of passive loss exclusion will penalize independents who raise capital through partnerships with other independents
Recent Pronounced “Dislocation” between WTI oil prices and HHUB gas prices

Source: Bloomberg; 1991 figures are from 01-24-1991 to 12-31-1991; 2011 figures are from 01-01-2011 to 04-18-2011
Fighting for market share for electricity generation in the US

Coal – 1st place

Natural gas – 2nd place

Nuclear – 3rd place

Renewables – 4th place

Source: US EIA Annual Energy Outlook 2011 Early Release Overview
Trends in US natural gas production, 1990 to 2035

Figure 1. Shale gas offsets declines in other U.S. supply to meet consumption growth and lower need

U.S. dry gas production (trillion cubic feet per year)

Source: US EIA Annual Energy Outlook 2011 Early Release Overview
Are shale gas resources a truly global phenomenon?

<table>
<thead>
<tr>
<th>Technically Recoverable Shale Gas Resources (Tcf)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>180</td>
</tr>
<tr>
<td>Poland</td>
<td>187</td>
</tr>
<tr>
<td>United States</td>
<td>862</td>
</tr>
<tr>
<td>Canada</td>
<td>388</td>
</tr>
<tr>
<td>Mexico</td>
<td>681</td>
</tr>
<tr>
<td>China</td>
<td>1,275</td>
</tr>
<tr>
<td>Australia</td>
<td>396</td>
</tr>
<tr>
<td>South Africa</td>
<td>485</td>
</tr>
<tr>
<td>Libya</td>
<td>290</td>
</tr>
<tr>
<td>Algeria</td>
<td>231</td>
</tr>
<tr>
<td>Argentina</td>
<td>774</td>
</tr>
<tr>
<td>Brazil</td>
<td>226</td>
</tr>
<tr>
<td>Other Surveyed Countries</td>
<td>647</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,622</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Proved Reserves (Tcf)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>6,609</td>
</tr>
</tbody>
</table>

*Source: US EIA "World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States" (April 5, 2011)*
Global warming potential of methane

<table>
<thead>
<tr>
<th>Industrial Designation or Common Name (years)</th>
<th>Chemical Formula</th>
<th>Lifetime (years)</th>
<th>Radiative Efficiency (W m–2 ppb–1)</th>
<th>SAR(100-yr)</th>
<th>20-yr</th>
<th>100-yr</th>
<th>500-yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>CO2</td>
<td>See below</td>
<td>1.4x10–5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Methane</td>
<td>CH4</td>
<td>12</td>
<td>3.7x10–4</td>
<td>21</td>
<td>72</td>
<td>25</td>
<td>7.6</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>N2O</td>
<td>114</td>
<td>3.03x10–3</td>
<td>310</td>
<td>289</td>
<td>298</td>
<td>153</td>
</tr>
</tbody>
</table>

The CO$_2$ response function used in this report is based on the revised version of the Bern Carbon cycle model used in Chapter 10 of this report (Bern2.5CC; Joos et al. 2001) using a background CO$_2$ concentration value of 378 ppm. The decay of a pulse of CO$_2$ with time $t$ is given by

$$a_0 + \sum_{i=1}^{3} a_i \cdot e^{-t/\tau_i}$$

Where $a_0 = 0.217$, $a_1 = 0.259$, $a_2 = 0.338$, $a_3 = 0.186$, $\tau_1 = 172.9$ years, $\tau_2 = 18.51$ years, and $\tau_3 = 1.186$ years.

Growth in methane emissions

since 1990


<table>
<thead>
<tr>
<th>Year</th>
<th>1990</th>
<th>2005</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated emissions (million metric tons CO₂e)</td>
<td>768.8</td>
<td>669.2</td>
<td>724.2</td>
<td>730.9</td>
</tr>
<tr>
<td>Change from 1990 (million metric tons CO₂e)</td>
<td>-99.6</td>
<td>-44.7</td>
<td>-37.9</td>
<td></td>
</tr>
<tr>
<td>(percent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average annual change from 1990 (percent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change from 2005 (million metric tons CO₂e)</td>
<td>54.9</td>
<td>61.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(percent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change from 2008 (million metric tons CO₂e)</td>
<td>6.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(percent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 18. U.S. methane emissions from energy sources, 1990-2009

SO2, NOx, and particulate emission rates

Mercury emission rates

CO₂ emissions normalized by gross output

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Well site during active drilling to the Marcellus Shale formation in Upshur County, West Virginia in 2008. Photo: West Virginia Surface Owners Rights Organization.
Natural Gas drilling rigs
Jonah Field, Wyoming
Photo: Joel Sartore

Hydro-Fracking drill sites
Dimock, Pennsylvania
Photo: J. Henry Fair
**FIGURE I-8. MUD RESERVE PIT**
Torn liners can lead to groundwater contamination.

**FIGURE I-9. WASTE PIT**
Waste pits for fluids and sediments associated with gas processing. These can contain water, sand, hydrocarbons, glycol and other chemicals.

**FIGURE I-10. FRAC PIT**
Unlined pits may allow toxic fracturing fluids to seep into soil and contaminate groundwater.

Source: www.ogap.org
Oil and gas drilling near the Roan Plateau.

Photo: Ecoflight.info

Salt build up on pit.

Photo: www.ogap.org
Multiple factors favor usage and development of global shale gas

- Enormous domestic/global resource base
- Favorable economics to alternative fuels
- Fukushima tragedy increases nuclear anxiety
- Middle East & North Africa political turmoil creates oil supply uncertainty
- Numerous opportunities for beneficial usage vs. competing fuels
- Incremental market share gains equal significant economic and environmental benefits
- U.S. federal policy confusing but appears supportive
2011 worldwide shale gas: breaking OPEC’s strangle hold
The big 4 major U.S. gas shales are world class discoveries that can reduce foreign oil usage dramatically.

Through continued technological advancements, we potentially have even more giant natural gas fields in North America.
The Discovery of shale gas has created a new age of natural gas abundance for the U.S.

Total Potential Natural Gas Resources (trillion cubic feet)

*From 1990-2006, traditional resources include shale gas, which was not broken out separately by the PGC until 2008.

Source: Potential Gas Committee Report, June 2009
Recent discoveries are spread across the U.S. – 32 of 50 states now produce natural gas

Supply from U.S.: 85%
Supply is from N. America: 97%

Natural gas producing state
Non producing state
Low-risk, U.S. onshore asset base; not exposed to economic, geopolitical or technological risks internationally or in the Gulf of Mexico
In 2008, Domestic Production Was Expected To Flatten and Decline

Source: Navigant Consulting, Inc.
But shale discoveries have far exceeded EIA projections

Source: Navigant Consulting, Inc
Shale gas production accounts for virtually all the 22% growth in production since 2005

Source: EIA
Shale gas production is projected to account for 70% of production in 2012

Source: HPDI and SCI Estimates
Pipeline additions since 1998 have allowed natural gas to get to market at substantial transportation discounts to norms.

1998

20,000 MILES
Of New Transmission Pipeline

97 BCFD
Capacity Added in US in the Last 10 Years

Growth Driven By The Need To:

ACCESS NEW SUPPLIES
•Expanding Production From New Fields
•Imports From Canada

MEET INCREASED DEMAND
From New Gas-Fired Power Plants
U.S. Shale Gas to the Rescue – Crude Trading at Historical Highs to U.S. Natural Gas

Crude to Natural Gas Spread

Source: Bloomberg
How natural gas is used today

- 3% Transportation
- 14% Commercial
- 32% Industrial
- 30% Electric Power
- 21% Residential

Source: EIA, Natural Gas Year In Review, 2009
Various power generation technology cost comparisons: natural gas wins again

<table>
<thead>
<tr>
<th>Technology</th>
<th>Capital Cost ($/kw)</th>
<th>Delivered Fuel Cost ($/mmbtu)</th>
<th>Levelized Cost (cents/kwh)</th>
<th>U.S. Installed Capacity - Net Summer Capacity (GW)</th>
<th>Energy Consumption to Produce 1 kw</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coal</strong></td>
<td>$2,000-$2,500</td>
<td>3.71</td>
<td>4.0-5.0</td>
<td>321</td>
<td>~1lb of coal</td>
</tr>
<tr>
<td>Natural Gas--Combined Cycle</td>
<td>$800-$1,000</td>
<td>4.56</td>
<td>3.5-4.5</td>
<td>225</td>
<td>7,500 btu</td>
</tr>
<tr>
<td>Natural Gas--Peaker</td>
<td>$500-$800</td>
<td>4.75</td>
<td>6.0-8.0</td>
<td>207</td>
<td>12,000 btu</td>
</tr>
<tr>
<td>Hydro</td>
<td>$4,000+</td>
<td>Free</td>
<td>4.0</td>
<td>100</td>
<td>Free</td>
</tr>
<tr>
<td>Nuclear</td>
<td>$5,000-$8,000</td>
<td>0.67</td>
<td>8.4</td>
<td>102</td>
<td>&lt;1g of uranium</td>
</tr>
<tr>
<td>Oil</td>
<td>$700-$1,000</td>
<td>13.00</td>
<td>15.0-16.0</td>
<td>56</td>
<td>10,000 btu</td>
</tr>
<tr>
<td>Solar PV</td>
<td>$4,000-$6,000</td>
<td>Free</td>
<td>15.0-50.0</td>
<td>2</td>
<td>Free</td>
</tr>
<tr>
<td>Wind--Onshore</td>
<td>$1,300 - $1,700</td>
<td>Free</td>
<td>6.0-9.0</td>
<td>41</td>
<td>Free</td>
</tr>
<tr>
<td>Wind--Offshore</td>
<td>$4,000+</td>
<td>Free</td>
<td>18.0-20.0</td>
<td>0</td>
<td>Free</td>
</tr>
</tbody>
</table>

Source: Simmons & Company International 2011

Note:
*Global gas capacity is not available by peaker and combined cycle
*US installed capacity is current from SNL.
*Global installed capacity is from the 2006 IEA World Energy Outlook and is actual 2006 data.
Natural gas power generation provides the cheapest option for power generation

Source: EIA
Coal power must run the regulatory gauntlet which creates future ratepayer price uncertainty.

Possible timeline for environmental regulatory requirements for the utility industry:

- **Ozone**: Begin CAIR Phase I Seasonal NOx Cap, Reconsidered Ozone NAAQS, NOx Primary NAAQS, CAIR Vacated, CAIR Remanded, Revised Ozone NAAQS.
- **SO2/NO2**: SO2 Primary NAAQS, Final Transport Rule Expected (CAIR Replacement), Effluent Guidelines proposed rule expected, NO2 Primary NAAQS, Transport Rule proposal issued (CAIR Replacement), CO2 Regulation.
- **CAIR/Transport**: SO2/NO2 Secondary NAAQS, Final Transport Rule II (NOx), CAIR/Transport proposal issued (CAIR Replacement), Effluent Guidelines Final rule expected, 316(b) final rule expected, NOx Cap Reconsidered Ozone NAAQS.
- **Water**: Effluent Guidelines Compliance 3-5 yrs after final rule, Effluent Guidelines Final rule expected.
- **PM2.5**: Proposed Rule for CCBs Management, Final Rule for CCBs Management, Revised PM-2.5 SIPs due ('97).
- **Ash**: HAPS MACT proposed rule.
- **Hg/HAPS**: Final EPA Nonattainment Designations, HAPS MACT final rule expected.
- **CO2**: Reconsidered Ozone NAAQS.
- **CO2**: CO2 Regulation.
- **316(b) proposed rule expected**: Final Transport Rule Phase I Reductions.
- **Transport Rule Phase II Reductions**: New PM-2.5 NAAQS Designations, HAPS MACT Compliance 3 yrs after final rule.
- **Final Transport Rule Phase II Reductions**: Final Transport Rule Phase II Reductions, Effluent Guidelines Final rule expected.
- **Final Transport Rule Phase I Reductions**: Effluent Guidelines Final rule expected.
- **Final Transport Rule Phase II Reductions**: Final Transport Rule Phase II Reductions, Effluent Guidelines Final rule expected.
- **Final Transport Rule Phase I Reductions**: Final Transport Rule Phase I Reductions, Effluent Guidelines Final rule expected.
- **Final Transport Rule Phase II Reductions**: Final Transport Rule Phase II Reductions, Effluent Guidelines Final rule expected.
As existing U.S. coal plants age, more coal will be forced to retire

U.S. coal capacity (GW) by age

Source: SNL Energy
Lower feedstock prices and cheap dollar provides incentive for reindustrialization of U.S.

Direct industrial gas demand (in bcf/d)

Source: EIA
Shale gas reduces price volatility associated with natural gas supplies
Shale production economics provide substantial cost benefit to broad range of consumers

Breakeven Henry Hub price for productive capacity* of analyzed plays

- Less than $3.00 per Mcf: 18.2 Bcf per Day
- Less than $4.00 per Mcf: 70.5 Bcf per day
- Less than $5.00 per Mcf: 74.1 Bcf per day
- Less than $7.00 per Mcf: 108.6 Bcf per day

Source: IHS CERA 2010

* Forty years of plateau proved, possible, and potential productive capacity
Liquids heavy shale provides ethane-based crackers with significant advantage over naptha

World indicative ethylene cash costs
CNG economics provide attractive options to gasoline and diesel

<table>
<thead>
<tr>
<th>Figure 24: CNG Economics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CNG Price Buildup</strong></td>
</tr>
<tr>
<td>NYMEX Natural Gas Price ($/Mcf)</td>
</tr>
<tr>
<td>NG to CNG Conversion Factor</td>
</tr>
<tr>
<td>CNG Feedstock Price ($/GGE)</td>
</tr>
<tr>
<td>Transport/O&amp;M/Taxes ($/GGE)</td>
</tr>
<tr>
<td>Margin ($/GGE)</td>
</tr>
<tr>
<td>CNG Pump Price ($/GGE)</td>
</tr>
<tr>
<td>After 5% Efficiency Penalty ($/GGE)</td>
</tr>
<tr>
<td>Retail Gasoline Price ($/gal)</td>
</tr>
<tr>
<td>Natural Gas Savings ($/GGE)</td>
</tr>
<tr>
<td>Natural Gas % Savings (GGE)</td>
</tr>
</tbody>
</table>

Source: SCI Estimates and Various
Natural Gas Vehicles are an environmentalist’s dream

- Compared to gasoline or diesel, NGVs:
  - Reduce CO\textsubscript{2} emissions: 20-30%
  - Reduce CO emissions: 70-90%
  - Reduce NOx emissions: 75-95%
  - Reduce Particulate Matter emissions: 90%
  - Reduce VOC emissions: 89%

Honda Civic Gx (CNG)
ACEEE’s “Greenest Vehicle” for the 8\textsuperscript{th} year in a row!
2011 Beat the Volt and the Leaf!
Natural Gas is the fuel of choice for a cleaner environment

### Fossil fuel emission levels

Pounds per Billion Btu of Energy Input

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Natural Gas</th>
<th>Oil</th>
<th>Coal</th>
<th>The Natural Gas Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>117,000</td>
<td>164,000</td>
<td>208,000</td>
<td>44%</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>40</td>
<td>33</td>
<td>208</td>
<td>81%</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>92</td>
<td>448</td>
<td>457</td>
<td>80%</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>1</td>
<td>1,122</td>
<td>2,591</td>
<td>99.9%</td>
</tr>
<tr>
<td>Particulate Matter</td>
<td>7</td>
<td>84</td>
<td>2,744</td>
<td>99.7%</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.000</td>
<td>0.007</td>
<td>0.016</td>
<td>100%</td>
</tr>
</tbody>
</table>

If serious about environmental pollution, why do environmental NGO’s engage in such vilification of shale gas?
Natural gas exploration and production – a highly regulated process

- The **Clean Water Act** regulates surface water discharges and storm-water runoff.

- The **Clean Air Act** sets rules for air emissions from engines, gas processing equipment and other sources associated with drilling and production activities.

- The **Safe Drinking Water Act** regulates the disposal of fluid waste deep underground (far below fresh water supplies and separated by approximately one mile of impermeable rock).

- The **National Environmental Policy Act** requires permits and environmental impact assessments for drilling on federal lands.

- The **Occupational Safety and Health Act** sets standards to help keep workers safe. These include requiring Material Safety Data Sheets be maintained and readily available onsite for any chemicals used by workers at that location.

- The **Emergency Planning & Community Right-to-Know Act** requires storage of regulated chemicals in certain quantities to be reported annually to local and state emergency responders.
Horizontal drilling and hydraulic fracturing technologies have revolutionized the discovery and production of natural gas.

Modern drilling technology enables producers to achieve exponential growth in production per well. Horizontal drilling also provides a reduced surface footprint; one location can now replace ~ 6-10 wells from a surface area and production perspective.

- **Unconventional Wells**
  - Lower risk
  - “Manufacturing” process

- **Conventional Wells**
  - Higher risk
  - Geologic uncertainty & inconsistency

---

1  2  3  4  5  6

**Natural Gas Zones**
### Components of frac fluid – the facts

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Main Ingredient</th>
<th>Purpose</th>
<th>Other Common Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>99.5% Water &amp; Sand</td>
<td>Expand fracture and deliver sand</td>
<td>Landscaping, manufacturing</td>
</tr>
<tr>
<td>Sand (Proppant)</td>
<td>Water &amp; Sand</td>
<td>Allows the fractures to remain open so the gas can escape</td>
<td>Drinking water filtration, play sand, concrete and brick mortar</td>
</tr>
<tr>
<td>Other</td>
<td>~ 0.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gel</td>
<td>Guar gum or Hydroxyethyl cellulose</td>
<td>Thickens the water in order to suspend the sand</td>
<td>Cosmetics, baked goods, ice cream, toothpaste, sauces, and salad dressings</td>
</tr>
<tr>
<td>Friction Reducer</td>
<td>Petroleum distillate</td>
<td>&quot;Slicks&quot; the water to minimize friction</td>
<td>Used in cosmetics including hair, make-up, nail and skin products</td>
</tr>
<tr>
<td>Acid</td>
<td>Hydrochloric acid or muriatic acid</td>
<td>Helps dissolve minerals and initiate cracks in the rock</td>
<td>Swimming pool chemical and cleaner</td>
</tr>
<tr>
<td>Anti-Bacterial Agents</td>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water that produces corrosive by-products</td>
<td>Disinfectant; sterilizer for medical and dental equipment</td>
</tr>
<tr>
<td>Scale Inhibitor</td>
<td>Ethylene glycol</td>
<td>Prevents scale deposits in the pipe</td>
<td>Used in household cleansers, de-icer, paints, and caulk</td>
</tr>
<tr>
<td>Breaker</td>
<td>Ammonium Persulfate</td>
<td>Allows a delayed break down the gel</td>
<td>Used in hair coloring, as a disinfectant, and in the manufacture of common household plastics</td>
</tr>
<tr>
<td>Corrosion inhibitor</td>
<td>n,n-dimethyl formamide</td>
<td>Prevents the corrosion of the pipe</td>
<td>Used in pharmaceuticals, acrylic fibers and plastics</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Borate Salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Used in laundry detergents, hand soaps and cosmetics</td>
</tr>
<tr>
<td>Iron Control</td>
<td>Citric Acid</td>
<td>Prevents precipitation of metal oxides</td>
<td>Food additive; food and beverages; lemon juice ~7% citric acid</td>
</tr>
<tr>
<td>Clay Stabilizer</td>
<td>Potassium Chloride</td>
<td>Creates a brine carrier fluid</td>
<td>Used in low-sodium table salt substitute, medicines, and IV fluids</td>
</tr>
<tr>
<td>pH adjusting agent</td>
<td>Sodium or potassium carbonate</td>
<td>Maintains the effectiveness of other components, such as crosslinkers</td>
<td>Used in laundry detergents, soap, water softener and dish washer detergents</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Isopropanol</td>
<td>Used to increase the viscosity of the fracture fluid</td>
<td>Used in glass cleaner, multi-surface cleansers, antiperspirant, deodorants and hair-color</td>
</tr>
</tbody>
</table>

*Public Disclosure Now Provided by Major Producers at [www.FracFocus.org](http://www.FracFocus.org)*
Fracture stimulation and gas production are completely isolated from fresh water.

This rock is harder than concrete, so why do we feel secure in the Ted Williams Tunnel a few feet of concrete keeping us safe vs. 8,000’ of concrete-like rock separating frac fluids from the surface?
# Comparative Energy Water Usage

<table>
<thead>
<tr>
<th>Energy Resource</th>
<th>Range of Gallons of Water Used per MMBtu of Energy Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>0</td>
</tr>
<tr>
<td>Wind</td>
<td>0</td>
</tr>
<tr>
<td>Deep Shale Natural Gas</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Nuclear (uranium ready to use in plant)</td>
<td>8 - 14</td>
</tr>
<tr>
<td>Synfuel - Coal Gasification</td>
<td>11 - 26</td>
</tr>
<tr>
<td>Tar Sands</td>
<td>15 - 38</td>
</tr>
<tr>
<td>Oil Shale</td>
<td>20 - 50</td>
</tr>
<tr>
<td>Synfuel - Fisher Tropsch</td>
<td>41 - 60</td>
</tr>
<tr>
<td>Coal (ready to use in a power plant)</td>
<td>41 - 164</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>143 - 243</td>
</tr>
<tr>
<td>Oil – (electric sector)</td>
<td>1,200 – 2,420</td>
</tr>
<tr>
<td>Fuel Ethanol</td>
<td>2,510 – 29,100</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>14,000 – 75,000</td>
</tr>
</tbody>
</table>

Source: GWPC Report 2009, USDOE 2006 (other than CHK data)

If you care about water resources, you should massively favor natural gas vs. coal and nuclear.
Water use in Marcellus Shale area

Marcellus Shale water usage pales in comparison to other industries.

Total water use in Marcellus area: 3.6 trillion gallons per year

- Power Generation: 72%
- Public Supply: 12%
- Industrial and Mining: 16%
- Other Industrial and Mining: 16%
- Natural Gas Industry: Projected Use 0.1%

Notable other uses too small to show on chart: Irrigation: 0.1%, Livestock use: 0.01%

Total water use (surface water and groundwater) in central PA (32 county area), southern NY (10 County Area), northern WV (29 county area), western VA and MD (5 county area) and eastern OH (3 county area) by sector

Source: USGS Estimated Use of Water in US, County Level Data for 2000
Water intensity of transportation fuels

Compressed Natural Gas (CNG)
Source: Adapted from King and Webber 2008a; *Adapted from King and Webber 2008b, combined with data from USDOE 2006; Non-irrigated biofuels not shown on plot above

Gasoline with 10% irrigated ethanol blend: ~ 200 gallons water consumed per 100 miles driven
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