The First Hydraulic Fracturing Forum for Oil and Gas Extraction and Production

Texas Tech University
Lubbock, Texas

January 6, 2014
Agenda

Energy and the Environment,
Davis L. Ford, Ph.D., P.E., (N.A.E.),
Visiting Professor of Petroleum Engineering,
Texas Tech University

Water Management for Hydraulic Fracturing for Gas and Oil,
Danny D. Reible, Ph.D, P.E., (N.A.E.)
Maddox Distinguished Chair,
Texas Tech University

Getting Tight Oil and Gas Out of the Reservoir,
Hans Schuessler, Ph.D.,
Professor and Chair of Optical and Biomedical Physics,
Texas A&M University
(College Station, TX USA and Doha, Qatar)
Energy and the Environment

Davis L. Ford, Ph.D., P.E., (N.A.E.),
Visiting Professor of Petroleum Engineering,
Texas Tech University

Discussion led by Dr. Davis Ford
January 6, 2014
ENHANCED OIL AND GAS RECOVERY, WATER REUSE AND THE ENVIRONMENT

NOVEMBER, 2013
• DRILLING, COMPLETION, STAGING, HORIZONTAL, VERTICAL, AND ZIPPER FRACKING
• RENEWABLE ALTERNATIVE FUELS
• WATER, NEW AND USED, WATER DEMANDS, REUSE, FLOWBACK AND PRODUCED
• BASIC EXPLORATION AND PRODUCTION ECONOMICS, DEBT, AND INVESTING
• CONVEYANCE
• REGULATORY
• GLOBAL
• SUMMARY
ACKNOWLEDGEMENTS

I WOULD LIKE TO ACKNOWLEDGE THE FOLLOWING SOURCES IN THIS COMPILATION

- The technical staff at Clayton Williams Energy, including Clayton Williams, Matt Swierc, John Kennedy, Sam Lysee, Ron Gasser, Clay Pollard and others, all of whom gave me technical briefings and/or access to drilling, completion, and operational site locations
- The webinar seminars by Vinson Elkins
- Representatives of Stat Oil
- Field discussions with Halliburton, CWEI, and other drilling, development and completion service providers
- The Texas Water Board and Railroad Commission representatives
DRILLING, COMPLETION, STAGING, HORIZONTAL, VERTICAL, AND ZIPPER FRACKING
The discovery of enormous reserves (mostly proven) which are “tight” shale oil and gas has the potential of totally transforming the dependence of U.S. energy production and possible energy independence. This transformation is primarily attributable to horizontal drilling (now commonplace) and hydraulic fracturing (fracking or fracing or fracching).
In mid-2012, the U.S. is 95% or more dependent on fossil fuels (including nuclear) whereas the “green” energy sources such as ethanol, biofuels, solar, and wind are currently in the development and subsidy stages.
For example, the following have combined billions of proven reserve barrels of oil as well as trillions or more of cubic feet of gas:

* the Bakken Formation in parts of Wyoming, South Dakota, North Dakota, Montana and into Canada,

* the Marcellus Formation primarily in Pennsylvania, New York, and into Canada, and

* other similar formations in the Southwest:
  the Barnett Shale in north Texas
  the Eagle Ford Shale Formation in south and southwest Texas
  the Permian Basin in western Texas and southeastern New Mexico,
  the Anadarko Basin in Oklahoma and the Texas Panhandle,
  the Rockies in northern Colorado and Wyoming, and
  the Utica Shale in Ohio and surrounding areas.
• The world is currently in an energy transformation.

• Fossil fuels extraction technology is resulting in a worldwide exponential increase in the production of oil & gas.

• Water may be our most precious natural resource.

• What is the role of renewable energy?

• How do we maximize world energy production and concurrently minimize environmental impacts?
Fossil Fuels
- Natural Gas
- Petroleum Crude
- Coal
- Nuclear (different origin but from the earth and non-renewable)

Alternative Fuels
- Ethanol (corn based)
- Bio diesel (grasses, algae)
- Solar
- Wind Turbines
- Geothermal
- Others
George Mitchell, 94, dies: Oil man unlocked fracking

- MITCHELL ENERGY PURRED MONEY INTO DRILLING WELLS MUCH MORE CLOSELY THAN BEFORE.

- THEY DISCOVERED THE KEYS IN MAKING THE BARNETT SHALE WELLS MONEY MAKING AND COMMERCIAL

- GEORGE MITCHELL TURNED THE FOSSIL FUEL ON ITS HEAD..FROM ONE OF SCARCITY TO ONE OF ABUNDANCE

- HE CRACKED THE CODE
Hydraulic Fracturing Job Creation

Marcellus Shale Core Employment (PA)

20,000

10,000

Barnett (TX) (trend)

Eagle Ford (TX) (trend)

Marcellus (PA)

Source: PA Dept. of Labor & Industry
Natural Gas is the Least Cost Option for New Power Generation

A challenge to the construction of new coal-fired plants will be the high costs of equipping the plants to mitigate air emission problems.
Studies show fractures do not reach groundwater

Source: NPC (2012)
Groundwater Concerns Largely Unconfirmed by Studies

- Dimock, PA - EPA completed retesting of drinking wells in 2012
- Pavillion, WY - Heavy criticism of draft report, methodology and conclusions led EPA to review its findings
  - On June 21, 2013, EPA announced that it will **abandon** its investigation into Pavillion
  - Agency **will not** seek peer review or finalize its 2011 draft report
- Parker County, TX - Recently vacated an emergency order from December 2010, alleging contamination of drinking water supplies by gas wells in the Barnett shale, saying that gas detected in water most likely came from a much **shallower formation**
Global Market Trends (2012)
Source: CQG Inc; Energy Information Administration, DOE

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<th>Oil Price</th>
<th>Global Demand Ex., U.S.*</th>
<th>U.S. Demand*</th>
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<td>$150</td>
<td>72</td>
<td>22</td>
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<td>125</td>
<td>70</td>
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<td>100</td>
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<td>75</td>
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<td>50</td>
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<td>18</td>
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<tr>
<td>25</td>
<td>62</td>
<td>17</td>
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* Million bbl/day
North Dakota
Historical Oil Production
Barrels per day 1952-2012

1. First well in Bakken pool (1953)
2. First horizontal Bakken well (1987)
3. ND 9th in US oil production (2005)
4. EOG Parshall/Austin discovery (2006)
5. Staloil Olson 10-15 #1H well (2010)
Well pad design

- Top drive and traveling block
- Housing trailers
- Doghouse
- Shale shakers
- Pipe racks
- Catwalk
- Rig floor
- Blowout preventer
- Rig engines

LOCATION CONSTRUCTION

Statoil
Development plan

STACKED 1280 ACRE UNITS

1 mile

2 miles

Surface locations

4 Bakken x 3 Three Forks well development per 1280 acre unit

Bakken wells
Three Forks wells

Statoil
Working Rig, Horizontal Drilling (above)

Eagle Ford Shale Play (below)
Fracturing Fluid

Water (93.56%)
Fluid System (1.09%)

Sand (2.56%)

Water provided by Operator

Acid

Corrosion Inhibitor
Surfactant
Friction Reducer
Biocide
Scale Inhibitor
Breaker

Halliburton, 2012
<table>
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<tr>
<th>Classes of Additives</th>
<th>Purpose</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Acid</td>
<td>Facilitates entry into rock formations</td>
<td>Hydrochloric acid</td>
</tr>
<tr>
<td>Biocides</td>
<td>Kill bacteria/reduce Risk of fouling</td>
<td>Glutaraldehyde, 2,2 Dibromo-3-nitriopropionamide</td>
</tr>
<tr>
<td>Breaker</td>
<td>Facilitate proppant Entry</td>
<td>Peroxodisulfates</td>
</tr>
<tr>
<td>Clay stabilizer</td>
<td>Clay stabilization</td>
<td>Salta, ie tetramethylammonium Chloride</td>
</tr>
<tr>
<td>Corrosion inhibitor</td>
<td>Well maintenance</td>
<td>Methanol</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Facilitate proppant Entry</td>
<td>Potassium hydroxide</td>
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<tr>
<td>Friction reducers</td>
<td>Improve surface Pressure</td>
<td>Sodium acrylate, polyacrylamide</td>
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<tr>
<td>Gelling agents</td>
<td>Proppant placement</td>
<td>Guar gum</td>
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<tr>
<td>Iron control</td>
<td>Well maintenance</td>
<td>Citric acid, thioglycolic acid</td>
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<tr>
<td>Scale inhibitor</td>
<td>Prevention of Precipitation</td>
<td>Ammonium chloride, ethylene glycol, polyacrylate</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Reduction in fluid tension</td>
<td>Methanol, isopropanol</td>
</tr>
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</table>
## Natural Sand, RCS, Ceramic Pricing

### Pricing Guide

### 20/40 Finished Sand

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Crush</th>
<th>Color</th>
<th>Price/Ton</th>
<th>Price/Unit</th>
<th>Notes</th>
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<tr>
<td>Lake Shore</td>
<td>North</td>
<td>4K</td>
<td></td>
<td>$69</td>
<td>$0.0345</td>
<td>10k T/M FOB Plant</td>
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<tr>
<td>Aztec Sand</td>
<td>South</td>
<td>4k</td>
<td></td>
<td>$88</td>
<td>$0.044</td>
<td></td>
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<tr>
<td>East Meadow</td>
<td>South</td>
<td>4c-5K</td>
<td>Off White</td>
<td>$103</td>
<td>$0.052</td>
<td>Min 10k tons/4k - Rail loaded $115/ton</td>
</tr>
<tr>
<td>Eastern Hills</td>
<td>South</td>
<td>5K</td>
<td>Off White</td>
<td>$100 - Negotiable</td>
<td>$0.05</td>
<td></td>
</tr>
<tr>
<td>East Meadow</td>
<td>South</td>
<td>5k</td>
<td>Off White</td>
<td>$115</td>
<td>$0.0575</td>
<td></td>
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<tr>
<td>20/40 Civil War Sand</td>
<td>South</td>
<td>5k</td>
<td></td>
<td>$65</td>
<td>$0.0325</td>
<td>20k T/M FOB Plant</td>
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<tr>
<td>Great Plains</td>
<td>North</td>
<td>6K</td>
<td>White</td>
<td>$86/10/1yr, $84/10/3yr, $84/10/5yr</td>
<td>$0.043/ft, $0.04225/ft, $0.042/ft</td>
<td>Available August</td>
</tr>
<tr>
<td>East Hills</td>
<td>South</td>
<td>6K</td>
<td>White</td>
<td>$114 - Negotiable</td>
<td>$0.057</td>
<td>$129 Loaded/Min 10k T/Week UP Rail &amp; Barge</td>
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<tr>
<td>Southern Belle</td>
<td>South</td>
<td>6K</td>
<td>White</td>
<td>$100</td>
<td>$0.050</td>
<td>Available Now</td>
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<tr>
<td>Southern Pleasure</td>
<td>South</td>
<td>6K</td>
<td>Off White</td>
<td>$100</td>
<td>$0.05</td>
<td>78k T/M - FOB Plant</td>
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<td>Blanco Silica</td>
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<td>6k</td>
<td>Off White</td>
<td>$70</td>
<td>$0.035</td>
<td>2,200 T/M</td>
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<tr>
<td>Wynona Special</td>
<td>North</td>
<td>6K</td>
<td>White</td>
<td>$85</td>
<td>$0.0425</td>
<td>Available July - 30k T/M</td>
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<tr>
<td>Lone Ranger</td>
<td>Texas</td>
<td>5K</td>
<td></td>
<td>$46</td>
<td>$0.02275</td>
<td>15k tons - loaded on rail</td>
</tr>
</tbody>
</table>

Source: [www.downholetrader.com](http://www.downholetrader.com)
Proppant Sand Mining and Processing Operations
(Central Texas)
Proppant Sand Mining and Processing Operations
(Central Texas)
Processed Frac Sand, Storage, and Truck Delivery Area to Fracking Locations
Pictorial Fracking Process

by

Davis L. Ford

Regarding: CWEI Fracking Contract with Halliburton

Site Visits:
2011: Andrews County, Texas
2012: Reeves County, Texas
Simplified Flow Diagram
Hydraulic Fracking Process

Source of Fresh Injection Water
Surface Impoundment
Vol Approx 2 Million Gallons

Frac Tank On Site Supply Water
(From Off Site Surface Impoundment)

Gel Blender
Mixes Surfactants
Gel

"T" Bell

Mixing Blender

Manifold

Injection Pumps

Well Injection Bore,
(Perforated)
Cased & Cemented
Plugged for Staging
As Required

Oil/Gas

Recycled Mud,
Produced Water,
Recovered Frac Water

Lined Surface
Impoundments

Redeployment or
Off-Site Disposal
As Required
Fresh Water Reservoir for 12-Stage Frack (to 11,000 ft depth) 2 Million Gal. Fresh Water Required
Fresh Water Then Pumped to a Series of Frack Tanks at Site
The Equipment Starts to Arrive
Everything Related to Frack Process is Mobile
On Site
Haliburton on Contract with CWEI
Mountain Mover
Complex Automated Proppant System
Massive Mobile Pumps and Appurtenances Arrive
Chemicals Arrive on Site
This Chemical Additive contains
"Ethanol and Heavy Aromatic Naptha"
The Mobile Site
“Command and Control Center”
Haliburton Frack Team Gets Last Minute Instructions on Safety and Operations
The “T Belt” Mixing Blender, Frack Water, Gel, Biocides, and Clay, Surfactant Recipe Is Fed to the Injection Pumping System for Injection into the Well Casing, Perforated, and Ready for the High Pressure Fracturing Process
Operational Control Metrics During the Fracking Process in the Various Zones Are Primarily Pressure, Injection Velocity and Continuously Monitored Viscosity
Schematic of Modern Drilling Technology Using Staging & Enhanced Oil & Gas Extraction Techniques

pipeline
rail
trucking
NGL
pay
flowback
produced water
flowback
storage tankage
renew & recycle
disposal
renew & recycle
storage tankage
wellbore
surface casing
intermediate casing
production casing
production tubing
packers -- direct flow
or production thru tubing
packers -- direct flow
or production thru tubing
plugs provide isolation
between stages
vertical, directional and/or horizontal
Note: All casing is cemented as per regulation and professional practice.
STEP ONE

This represents cement between the wellbore and the casing.

These are plugs—CP Hanks for Completions Plug—made out of material that is easy to get:

Process:
Run nitrite & perforate Stage 1.
Frac Stage 1.
Run: variable 5 & CP @ 10,000 psi & perforate Stage 2.
Frac Stage 2.
Run: variable 7 & CP @ 10,000 psi & perforate Stage 3.
Frac Stage 3.
Continue same process.

The plug is set about the stage that was just fractured to bring the stage from the next.

Note: The plugs are solid and will not allow flow from above or below.

<table>
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<tr>
<th>Stage 1</th>
<th>1,000 psi</th>
<th>2,000 psi</th>
<th>3,000 psi</th>
<th>4,000 psi</th>
<th>5,000 psi</th>
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<td>12</td>
<td>14</td>
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<th>7,000 psi</th>
<th>8,000 psi</th>
<th>9,000 psi</th>
<th>10,000 psi</th>
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<td>24</td>
<td>26</td>
<td>28</td>
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<td>36</td>
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<th>12,000 psi</th>
<th>13,000 psi</th>
<th>14,000 psi</th>
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<tr>
<td>Plug 5</td>
<td>40</td>
<td>42</td>
<td>44</td>
<td>46</td>
<td>48</td>
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STEP TWO

After track job is complete, we run a drill bit inside the production casing & drill up & remove all plugs used for isolation during track.

[Diagram with detailed measurements and annotations]
This represents a packer. After all of the plugs are drilled up, we run a packer that isolates the production casing above the packer & forces all flow up the tubing to the surface facilities. Flowing thru tubing with a smaller ID is more efficient than flowing up production casing with large ID... friction.
ZIPPER FRACTURING IS A TECHNOLOGY FOR ENHANCING A MULTIPLE FIELD NETWORK IN PAY FORMATIONS BY OPTIMIZING THE PLACEMENT OF FRACTURES ALONG THE DEVIATED WELLBORES, STAGGERING THE PERFORATIONS
Summary

Drilling & Completion Sequencing

- Drilling commences with drilling fluid (MUD) pumped through drill bit and recirculated through borehole annulus to cool, attract cuttings, and reduce friction.

- At a prescribed depth, surface casing is installed and cemented in place between the well bore and the surface casing.

- When drilling to deeper depths, intermediate casing installed on a drill and casing sequence, all cemented in place.

- In multi-stage drilling, the well is fracked through the perforations in selected “pay” zones. Plugs are inserted to allow staging, and packers are installed from the outside of the inserted production tubing to the inside of the production casing. When each of the stage plugs (bottom to top) are drilled open as the production tubing is inserted, all flow (“pay” fluids and flowback/produced water) from all perforations moves to the surface (pressure/pumping) through the production tubing, through the surface valving and control appurtenances, and separated accordingly. (See Steps ONE, TWO, THREE and FOUR on Flow Diagram Schematic.)

- A multiple valved “Christmas Tree” is installed at the surface and flanged to the top of the casing and the tubing is attached below the tree. This allows control of the flow rate of fluids from the production zone. Acid is pumped down the well as required and through the perforations to dissolve limestone channels as well as other enhancements.

- In the pump system, a sucker rod is inserted and attached to a surface pump jack and production commences.

- In multi-stage fracturing, the production tubing is also used to drill out all stage plugs from the bottom up.
The extent of oil and gas development in the Texas Eagle Ford formation, 2012
Sources of Methane in Water Wells

- Anthropogenic contamination (e.g., improperly sealed well)
- Natural contamination (migration along a fault)
- Microbial gas (produced in situ in the Smullum aquifers)

Kohlbecker, GSI 2011
Vacuum Chamber

Detection Cylinder
Laser Source
Water Use in Hydraulic Fracturing Operations

Potential Drinking Water Issues

- Water availability
- Impact of water withdrawal on water quality

- Release to surface and ground water (e.g., on-site spills and/or leaks)
- Chemical transportation accidents

- Accidental release to ground or surface water (e.g., well malfunction)
  - Fracturing fluid migration into drinking water aquifers
  - Formation fluid displacement into aquifers
  - Mobilization of subsurface formation materials into aquifers

- Release to surface and ground water
  - Leakage from on-site storage into drinking water resources
  - Improper pit construction, maintenance, and/or closure

- Surface and/or subsurface discharge into surface and ground water
  - Incomplete treatment of wastewater and solid residuals
  - Wastewater transportation accidents
Fracking Produces Less Greenhouse Gases Than Previously Estimated

(The University of Texas Study by Cockrell College of Engineering, 2013)

- Research found that 99% of methane gas is captured during fracking, most of remaining gas coming from pneumatic devices;
- Estimates of fracking methane residuals is in line with EPA estimates;
- Data published in Proceedings, National Academy of Science;
- The data included those from 9 industries, all of which gave independent researchers unprecedented and total access to field sites, procedures and data-production/analysis;
- The environmental defense fund and 9 industries sponsored the study, just released and now public, and
- E&P companies and “Environmentals” agree that methane captured reduces both greenhouse gases and produces more profit to energy companies.
A recent finding from The University of Texas Energy Institute notes there “is no link between extraction (fracking) operations and groundwater contamination.” The fracking operations that “we’ve seen are of no, minor or small, impact.”

•Austin American Statesman, Section B, November 10 (2011)
Remember:
GDP = Consumption
   Investments
   Government spending
   Exports minus Imports

Conclusion:
When the U.S. becomes energy independent, the GDP goes up accordingly. This is a major national issue.
Renewable Alternative Fuels
FEDERAL SUBSIDIES FOR ENERGY  
(DOLLARS PER MEGAWATT HR)  
(U.S. DEPARTMENT OF ENERGY, 2011)

<table>
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<tr>
<th>Energy Source</th>
<th>Subsidy (in $)</th>
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<tr>
<td>OIL AND GAS</td>
<td>0.64</td>
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<tr>
<td>HYDRO</td>
<td>0.84</td>
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<tr>
<td>COAL</td>
<td>0.64</td>
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<td>NUCLEAR</td>
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<td>WIND</td>
<td>56.29</td>
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<td>SOLAR</td>
<td>775.64</td>
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Wind turbines have approximately 2.5 megawatts capacity per unit, and the cost per unit is approximately 1.5 million dollars (2010). They are heavily subsidized by generous tax credits. Even then, the payback period is 7 to 10 years, far longer than most investment standards for new or expansion projects. Typical generation time is only in the range of 40% or less.

Extensive gathering lines and step-up transformers are required to transfer the wind generated power to transmission lines and equitable cost allocation in transmission lines is complex. (G. Skypala Interview, 2011)

The current U.S. transmission system was not built—and thus is not sufficient—to integrate planned and potential generation sources such as solar and wind.
Top 10 Total Installed Capacity by MW as of Dec. 31, 2008

Source: Global Wind Energy Council (GWEC)

Courtesy of Wind Today

www.windtoday.net

Booth #4340
SOLAR AND WIND EXPERIENCE IN GERMANY

- About 25% of power generation capacity is wind or solar
- Generous subsidies were given on the premise it would minimize import fossil fuel
- The consumer price now has gone up. The euro price has doubled per kWhr in the last 10 years.
- Gas fired plants were decommissioned and nuclear plants are being shut down.
- A major transformation is taking place. The future now appears to be natural gas and much of northern Europe sees fossil fuel (mostly gas) in the future.
• 0.5 to 3 gallons of water is required to refine 1 gallon of crude oil to 1 gallon of gasoline.

• 1,500 gallons of water is required to ferment irrigated corn into 1 gallon of ethanol. The energy input to create ethanol exceeds its product energy.

• A wind farm requires 40,000 acres to produce 1,000 MW of power.
Cost of Corn $/bu

Ethanol Cost in Terms of Corn Purchase Only (dollars per gallon)*

* 1 bu = 2.75 gallon ethanol (White Energy)
Ethanol Technical Fact Sheet

- 95 ethanol producing plants in U.S., 31 under construction

- U.S. gasoline demand: 383 million gal/day
  If gasoline/ethanol blend is 10%,
  Ethanol demand = 38.36 million gal/day
  (14 million bu corn/day consumption)

- At the 10% blend, ethanol demand: approx. 50% of current national corn production would have to be dedicated to ethanol production.

- Sugar beets and sugar cane feedstock are more efficient than corn in the fermentation process.

- Water consumption for corn to ethanol production is 3.65 gallons water/gal ethanol. The refining of petroleum crude requires approximately 0.5 to 0.7 gal water/gal crude.

- Ethanol chemical properties make it difficult if not impossible to convey by pipeline.
Water---New and Used, Water Demands, Reuse, Flowback and Produced
Growing Demand for Fresh Water

- The use of fresh water as a fracking source brings up the question of alternative sources, i.e.,
  - 1. domestic wastewater effluents
  - 2. produced (mixed) water reuse, recycle
  - 3. treated industrial effluents
  - 4. flowback capture and recycle
- There are major technical and economic issues involved. The service providers have the obligation to develop frack water chemistry and formulation, critical for successful hydraulic fracking. Even though chemical disclosures are now required, the total chemistry and formulation for fracking water is precise and primarily proprietary.
- It is also interesting to note that the revenue per gallon of irrigation water, for example, corn, produces only a small fraction of revenue as produced per gallon of fresh water. The ratio is approximately 15,000 more dollars produced per fack gal. as compared to irrigation gal.
- As one cannot use oil as a food source like one can use corn, this leads to a totally different field of allocating fresh water for domestic consumption/industrial use in the most cost-effective and efficient way.
<table>
<thead>
<tr>
<th>Gallons Used: Drilling</th>
<th>Gallons Used: Fracturing</th>
<th>Millions Gallons Used: per Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>250,000</td>
<td>3,800,000</td>
<td>~4.0</td>
</tr>
<tr>
<td>600,000</td>
<td>5,000,000</td>
<td>~5.6</td>
</tr>
<tr>
<td>65,000</td>
<td>4,900,000</td>
<td>~4.9</td>
</tr>
<tr>
<td>85,000</td>
<td>5,500,000</td>
<td>~5.6</td>
</tr>
<tr>
<td>125,000</td>
<td>6,000,000</td>
<td>~6.1</td>
</tr>
</tbody>
</table>
Water Demand
Hydraulic Fracturing

- Barnett – 3 MM gal/well
- Haynesville – 6 MM gal/well
- Eagle Ford – 4 MM gal/well
- All approximately 1000 gallons/lateral ft of horizontal wells (80% between 500 and 1500 gal/ft)

Nicot and Scanlan, 2012
### Energy Water Use

<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>Shale Natural Gas</td>
<td>0.60-10 (process dependent)</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1-3</td>
</tr>
<tr>
<td>Coal (no slurry transport)</td>
<td>2-8</td>
</tr>
<tr>
<td>Coal (w/slurry transport)</td>
<td>13-32</td>
</tr>
<tr>
<td>Nuclear (processed uranium ready to use in plant)</td>
<td>8-14</td>
</tr>
<tr>
<td>Conventional Oil</td>
<td>8-20</td>
</tr>
<tr>
<td>Synfuel-Coal Gasification</td>
<td>11-26</td>
</tr>
<tr>
<td>Oil Shale Petroleum</td>
<td>22-56</td>
</tr>
<tr>
<td>Tar Sands Petroleum</td>
<td>27-68</td>
</tr>
<tr>
<td>Synfuel-Fisher Tropsch (coal)</td>
<td>41-60</td>
</tr>
<tr>
<td>Enhanced Oil Recovery (EOR)</td>
<td>21-2,500</td>
</tr>
<tr>
<td>Fuel Ethanol (from irrigated corn)</td>
<td>2,510-29,100</td>
</tr>
<tr>
<td>Biodiesel (from irrigated soy)</td>
<td>13,000-75,000</td>
</tr>
</tbody>
</table>


### Growing Demand for Fresh Water

The use of fresh water, particularly as fracking water, brings up the question of alternative sources, i.e.,

1. domestic wastewater effluents
2. produced (mixed) water reuse, recycle
3. treated industrial effluents
4. others
Average Range of Water Use (Gal.)
(Source: Tudorpickering Holt & Co., Reservoir Research, July (2010))

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>mmbtu Produced Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale Gas</td>
<td>10</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>20</td>
</tr>
<tr>
<td>Nuclear</td>
<td>30</td>
</tr>
<tr>
<td>Conventional Oil</td>
<td>40</td>
</tr>
<tr>
<td>Oil Shale</td>
<td>50</td>
</tr>
<tr>
<td>Coal/Slurry Transport</td>
<td>60</td>
</tr>
<tr>
<td>Ethanol/Irrigated Corn</td>
<td>2,500 to 29,100</td>
</tr>
<tr>
<td>Biodiesel/Irrigated Soy</td>
<td>14,000 to 75,000</td>
</tr>
</tbody>
</table>
Water Issues: Hydraulic Fracturing

1. Recycling companies cropping up everywhere (1/3 flowback of recycling targets). “A billion dollar market of musical chairs.”
2. A lot of sorting out between players and wannabes—“a feeding frenzy with lots of casualties”
3. Current modus operandi—to POTWs or injection disposal wells (little or no pretreatment)—Disposal wells—$1-2/1000 gal or less
4. EPA formulating standards for disposal wells (now at state level)
5. Economy in scale for clustered wells (drilled, fracked, producing)
6. Economics govern (<$1/1000 gal to $30-50/1000 gal)
7. Potential could be worse if propane or similar gases take the place of water for fracking (propane, CO₂, etc.)

Candidate Systems:
- Ozonation, UV
- Electrocoagulation—electrofied plates cation/anion separation
- Desalinization (RO)
- Water free—high pressure liquefied petroleum gas, CO₂, propane, etc. (recoverable for reuse or sales)

8. Domestic water supply for various wells (brackish water) approx. $2/1000 gal., one RO at each well plus conveyance costs
9. Energy costs for thermoelectric plants (EPRI) ~1500 Kw.hr/million gallons to 10,000 Kw.hr/million gallons
## Reuse/Recycling

<table>
<thead>
<tr>
<th></th>
<th>PA Marcellus</th>
<th>TX Barnett</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water availability</td>
<td>Abundant</td>
<td>Limited</td>
</tr>
<tr>
<td>Drilling water, MM gal</td>
<td>0.085</td>
<td>0.25</td>
</tr>
<tr>
<td>Hydraulic fracturing, MM gal</td>
<td>5.5</td>
<td>3.8</td>
</tr>
<tr>
<td>New unconventional wells 2012</td>
<td>1365</td>
<td>660</td>
</tr>
<tr>
<td>Wells completed 2012 (est)</td>
<td>540</td>
<td>500</td>
</tr>
<tr>
<td>Active horizontal wells 2012</td>
<td>3680</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>Salt water disposal wells</td>
<td>7-8</td>
<td>980 (12,000 in TX)</td>
</tr>
<tr>
<td>Flowback + produced (WW), MGD (est)</td>
<td>3.1</td>
<td>2</td>
</tr>
<tr>
<td>Fraction WW recovered</td>
<td>~0</td>
<td>~0</td>
</tr>
<tr>
<td>Fraction WW Reused</td>
<td>0.87</td>
<td>0.13</td>
</tr>
<tr>
<td>Fraction WW deep-well injected</td>
<td>0.13</td>
<td>0.87</td>
</tr>
</tbody>
</table>

*Silva et al. 2013*
FIGURE 3.6. WATER DEMAND PROJECTIONS BY USE CATEGORY (ACRE- FEET PER YEAR).*

IRRIGATION

MUNICIPAL

STEAM ELECTRIC

MANUFACTURING

MINING, LIVESTOCK, FRACKING

**LOCATION SPECIFIC: VERY IMPORTANT ON LOCAL SUPPLY AND DEMAND**

WATER FOR TEXAS 2012 STATE WATER PLAN

CHAPTER 3: POPULATION AND WATER DEMAND PROJECTIONS
FRESH WATER FROM THE TRINITY SANDS
(HOWARD COUNTY, TEXAS) ALL SCHEDULED
FOR FRACKING
PROXIMATE WATER DISTRICTS COMPETE FOR THIS WATER TO MEET GROWING DRINKING WATER DEMANDS
COMPLETED AND FRESH WATER FRACKED WELL IS NOW IN PRODUCTION
FLOWBACK AND PRODUCED WATER DISPOSED IN A CLASS 2 INJECTION WELL. OUT OF THE WATER CYCLE
Candidate Water Reuse Technologies

Chemical Oxidation (chlorine dioxide\textsuperscript{1}, ozone, peroxides, etc.)
Membrane Filtration (ultrafiltration, microfiltration, or equal)
Concentrators
Evaporative Crystallization
Biological (biochemical) Oxidation/Digestion (mesophilic or thermophilic)
Floculation/Sedimentation/Filtration
Blending
Reverse Osmosis (staging as required)
Electrocoagulation
Conventional Filtration
Disinfection (i.e. reuse of domestic treated effluent)

\textsuperscript{1} Chlorine Dioxide is a strong oxidant and effective as a disinfectant, leaving significantly few byproducts than conventional chlorination. It disinfects by oxidation—not chlorination.

In addition to flowback/produced water and the characteristics of the natural produced gas and crude sources, the other characteristic and composition of drilling fluids, treatment and workover fluids should be included in the chemicals of concern produced during the drilling, production and completion fluids.

Concept: Achieving Zero Discharge of Water
Source: Adams, Carl E., ENVIRON (July 2013)
Storage Options

- Frac Tanks
- Impoundments
- Large Capacity Above Ground Moveable Tanks
- Portadam
- Portable Bladders
City of Aurora, Colorado
Treated Effluent for Fracking Water in 2012

- The City of Aurora, Colorado has recently consummated at contract with Anadarko Petroleum Corporation (Houston, Texas) to use approximately 1.3 million gallons per day to be used for hydraulic fracturing in the Wattenberg field in northern Colorado. Anadarko will pay the City $9.5 million for this purpose, over five years. This daily cost to Anadarko is 3 to 4 times the going rate cost for the privilege. Therefore, the City will use this money to pay off water company debt and possibly a small rebate to current water customers. (Aurora Sentinel (July 5, 2012))

- This is an excellent example of water reuse, exchanging possibly fresh water for treated effluent, which is normally discharged to the South Platt River and finds its way to Nebraska.
City of Lubbock, Texas  
Treated Effluent Quality (Smith, et al)

<table>
<thead>
<tr>
<th>Analysis in mg/l</th>
<th>Lubbock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total hardness (as CaCO₃)</td>
<td>290</td>
</tr>
<tr>
<td>COD</td>
<td>32-129</td>
</tr>
<tr>
<td>BOD</td>
<td>8-22</td>
</tr>
<tr>
<td>Virus</td>
<td>probably present</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>20</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>8-19</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>1194-1235</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>2-6</td>
</tr>
<tr>
<td>Total N</td>
<td>12-15</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>2-4</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>5-8</td>
</tr>
<tr>
<td>Org.-N</td>
<td>3-4</td>
</tr>
<tr>
<td>Total P</td>
<td>11-12</td>
</tr>
<tr>
<td>Chloride</td>
<td>318</td>
</tr>
<tr>
<td>Calcium</td>
<td>39</td>
</tr>
<tr>
<td>Magnesium</td>
<td>24</td>
</tr>
<tr>
<td>Sodium</td>
<td>344</td>
</tr>
<tr>
<td>Potassium</td>
<td>16</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>236-262</td>
</tr>
<tr>
<td>Sodium adsorption-ratio</td>
<td>6</td>
</tr>
<tr>
<td>pH, units</td>
<td>7.4-7.5</td>
</tr>
<tr>
<td>Fecal coliform, MPN per 100 ml</td>
<td>&lt;200</td>
</tr>
</tbody>
</table>
### NPDES Produced Water Effluent Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average</th>
<th>Daily Maximum</th>
<th>Average</th>
<th>Daily Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6-9</td>
<td>9</td>
<td>6.5-9.0</td>
<td></td>
</tr>
<tr>
<td>BOD (5-day)(mg/L)</td>
<td>30</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conductivity (µg/L)</td>
<td></td>
<td></td>
<td>600</td>
<td>1,200</td>
</tr>
<tr>
<td>Total Suspended Solids (mg/L)</td>
<td></td>
<td></td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Total Dissolved Solids (mg/L)</td>
<td></td>
<td></td>
<td>500</td>
<td>1,000</td>
</tr>
<tr>
<td>Total BTEX (µg/L)</td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Total Arsenic (µg/L)</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Total Barium (µg/L)</td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Total Cadmium (µg/L)</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Total Chromium (µg/L)</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Total Mercury (µg/L)</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Total Selenium (µg/L)</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Benzene (µg/L)</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

* Aquatic toxicity testing is also part of permit requirements.
Significance of Water to Our Business

More than ever, water is an integral part of the success of the oil and gas operations in shale basins.

So, think about this:

- No Water
- No Fracturing
- No Oil and Gas Company’s Resource Plays
I never drink water because of all the horrible things that fish do in it.  
*W.C. Fields*

Whisky is for drinking – water is what you fight over.  
*Mark Twain*

The major crisis the world faces in the future is the scarcity of water.  
*Senator Grasso*  
*Senate President, Republic of Italy (World Science Conference, Key Note Speech, Sicily, August, 2013)*

I like new water over old water, but what I really like is making old water new.  
*Davis L. Ford*

“Water, like religion and ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to it. People move when there is too little of it. People move when there is too much of it. People journey down it. People write, sing and dance about it. People fight over it. And all people, everywhere and every day, need it”  
*Mikhail Gorbachev*
Basic E&P Economics, Debt, Investing
• Virtually all new wells now are fractured. The cost ranges from 4 million to as high as 10 million dollars from spud to completion. Payout goals range from 2 to 4 years. Approximately 2 to 3 million gallons of water is required per frack, and 2,000 to 3,000 tons of proppant are required. (Proppant sand demand has risen from 10 million tons per year in 2009 to 37 million tons in 2013, nationwide.)

• Hedges (an investment position to offset potential losses/gains incurred by a companion investment) are used on occasions to protect the financial downside and cash flow of the E&G companies. For example, in the fourth quarter of 2013, a Hedge might cover 500,000 bbls of oil at a price of $100 per bbl and gas at 400,000 mmbtu at $3.50. Some companies use no Hedges while others use significant Hedges.

• Drilling and leasing activity in Texas is going up exponentially, measured by rig count and permits issued by the Texas Railroad Commission. Texas is now the tenth largest energy producer in the world. The U.S. is expected by most experts to be a net exporter of oil and gas in the next five to ten years. This is a huge impact on GDP (investments, spending, and exports-imports).
• There is a trend now to drill more horizontal fracked wells as compared to vertical.

• There is intensive interest now in Texas for developing new wells in the Wolfcamp, Permian, Eagle Ford, Barnet, and Cline Shale. For example, the Eagle Ford is currently producing over 800,000 bbls per day...even exceeding the production of the Dakotas Baakin areas. Millions of oil and gas reserves are now proven and production is expanding daily. California has extensive proven reserves (but, reluctant environmental constraints), as does the Marcellus, and there are other proven reserves in Northern Colorado and Wyoming, as well as the Midwest and eastern part of the U.S. Production continues to increase.

• Reservoir engineers are now able through seismic technologies to generally predict net yields of oil and gas per acre (TOC, formation permeability, porosity, and pay capture). This significantly increases leasing activities, lease price, and override values. It is very competitive in certain areas and becoming more so. Development and production drilling is very capital intensive, increasing farmouts, working interest, participation agreements,
joint ventures, and/or sale of master limited partnership (MLPs).

- Currently in Texas, leasing costs are up to a range of thousands of dollars per acre, depending on number of wells that can be drilled per unit area, and the number of acres one wants to lease in proven areas.

- Recently, more hydraulically fractured wells are using multiple staging and more legs in horizontal drilling (using techniques such as “zipper fracking”---alternative perforations between multiple horizontal legs).

- Most leases for a defined period of time have “drill it or lose it” provision which can be an accelerator to drill before losing or renewing a lease at a much higher cost. Such decisions require a thorough financial/cash flow analysis and expected yield, all subject to swings in oil and gas prices. This is why smaller E&P companies have to secure more debt capital from banks or bonds, find partners, and/or look to Hedging. Even in good times, it is a capital intensive and risky endeavor.
An associated but critical issue is the water resource management for continuing extraction of tight oil and gas. The use of fresh water (competing with irrigation and municipal demands) and/or reuse of treated municipal or industrial effluents, produced water, and/or flowback water are major considerations---site specific and economically driven.
Leasing Strategy

- Eagle Ford, Giddings Field, Austin Chalk
- Formation Definition is based on age and depth---not coordinates
- Leases with landowners have drilling depth limitations---normally 5 year leases---drill or lose
- Landowners get a price per acre and royalties---all negotiated
- Some leases can be “boxed in” by contiguous production or “protection” drilling
Desta Drilling

14 Rigs

7 – 1300 HP Rigs - Triples
- Drills vertical & horizontal wells
- Rated to 14,000’

5 – 1300 HP RG Rigs
- Drills vertical & horizontal wells
- Rated to 13,500’

2 – 1000 HP RG Rigs
- Drills vertical & horizontal wells
- Rated to 10,000’

Rig Benefits

- Utilized in our core areas of operations
- Provides cost control
- Provides for flexibility in Company strategy
- Personnel training and advancement potential
- Efficiencies from having loyal and well trained personnel
- Excess capacity contracted to 3rd parties

Desta Rig #16
Reeves County, Texas
# Summary of Hedges

<table>
<thead>
<tr>
<th>Swaps:</th>
<th>Oil</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bbls</td>
<td>Price</td>
</tr>
<tr>
<td>Production Period:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd Quarter 2013</td>
<td>300,000</td>
<td>$104.60</td>
</tr>
<tr>
<td>4th Quarter 2013</td>
<td>300,000</td>
<td>$104.60</td>
</tr>
<tr>
<td>2014</td>
<td>600,000</td>
<td>$99.30</td>
</tr>
<tr>
<td></td>
<td>1,200,000</td>
<td></td>
</tr>
</tbody>
</table>

<sup>(a)</sup> one MMBtu equals one Mcf a Btu factor of 1,000
CASH FLOW

- Generate more cash production
- Sell assets
- Reduce costs, overhead, operating
- Increase the price of the product
- Collect faster, pay slower
- Sell equity
- Secure a loan

Gross Domestic Product

- CONSUMPTION
- INVESTMENTS
- GOVERNMENT SPENDING
- EXPORTS – IMPORTS
MASTER LIMITED PARTNERSHIPS (MLPs)

- INDIVIDUALS, E&P FIRMS, AND INVESTMENT COMPANIES ARE USING MLPs AS PUBLICLY TRADED INSTRUMENTS AS AN ALTERNATIVE METHOD OF BUYING INTO THE ENHANCED TIGHT OIL GAS BOOM CURRENTLY EXPERIENCED IN THE U.S. TODAY.

- THIS IS ONE METHOD THAT PUBLICLY TRADED E&P FIRMS CAN RAISE CAPITAL TO FINANCE DRILLING, PRODUCTION, LEASING, AND PIPELINE OPERATIONS.

- INVESTORS ARE POURING IN CAPITAL WHICH SEEM “SAFE” SUCH AS PIPELINES WITH LONG TERM CONTRACTS.

- AS NOTED IN THE CHART BELOW, MONTHLY NET CASH INFLOWS TO MUTUAL FUNDS AND EXCHANGE TRADED PRODUCTS HAS INCREASED DRAMATICALLY OVER THE PAST YEAR (2013)


- MLPs ARE NOT TAX FREE, BUT CAN BE TAX DEFERRED, AND THE LONGER THE POSITION IS HELD, THE GREATER THE TAX BENEFIT. HOWEVER, THE TAXES ON MLPs CAN BE COMPLEX AND SHOULD BE CAREFULLY EXAMINED BEFORE INVESTING.
• There is a possibility that the MLP “bubble” can collapse and investors should understand the risks!
one of the 24 evaluations to establish a price per share. The solid line is the actual offer price by CWEI.

This was a complex and lengthy endeavor, but disputes were discussed, negotiated, and the merger was approved by unanimous consent, avoiding potential extended disagreements and potential litigations.

Figure 44
Historical NYMEX Percentiles - Oil

Figure 45
Southwest Royalties Transaction Committee
Reference Value Analyses Summary

Offer Price for LTD. Partnership
($172 Per Share)
Conveyance
Joining Forces
Kinder Morgan’s purchase of El Paso would create the nation’s largest natural-gas pipeline operator.

Combined: 66,702 miles

Natural Pursuit
Amid a decline in U.S. natural-gas prices, producers continue to tap rich shale deposits.
Pipeline Squeezes Reroutes Crude

- More crude is moving around the U.S. in trucks, barges, and rail than ever before. This is attributed to the highest production of crude in the last two decades which have outrun the pipeline systems, many of which are pointed in the wrong direction.

- This is requiring a major “replumbing” of the U.S. pipeline systems. Over 40 billion dollars of new pipelines are now being planned or under construction. With oil at $100 dollars per bbl or more, E&P companies don’t want to wait to market their product. Truck deliveries to refineries has increase almost 40% in the last two years, clogging roads and creating many regulatory bottlenecks.

- The Eagle Ford, for example, is producing more BBLs each day in remote southwest Texas areas, resulting in one pipeline reversal and demanding additional pipeline capacity.

- In the Dakotas (Baaing crude) over 60% is now moved to market by rail.

- With rail economic and safety concerns, as well as truck conveyance, it is predicted that the conveyance options as the U.S. continues more
CRUDE PRODUCTION TO THE POINT OF ENERGY INDEPENDENCE WILL DEPEND MORE ON EXPANDED PIPELINE CONSTRUCTION, WHICH IS MUCH LESS EXPENSIVE AND SAFER PER TRANSPORT MILE
Infrastructure Costs – Pipeline
Capitol Cost for Frack Water Pipeline

- Assume a 20 mile transport 20 bbls/min

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10” Cl. 200 PVC, G.J.</td>
<td>52800</td>
<td>LF</td>
<td>$17.00</td>
<td>$897,600</td>
</tr>
<tr>
<td>Booster Pump</td>
<td>1</td>
<td></td>
<td>$300,000.00</td>
<td>$300,000.00</td>
</tr>
<tr>
<td>Right of Way</td>
<td>20</td>
<td>MI</td>
<td>$32,000.00</td>
<td>$640,000.00</td>
</tr>
</tbody>
</table>

**TOTAL COST ESTIMATE**

$1,517,600.00

- $1,517,600 / 80,000 bbls well frack = $18.97/bbls
Water Transportation Concerns

**Trucking Water**
- Inefficient way to move water
- Local Relations
  - Environmental (Dust)
  - Destructive to Infrastructure
  - Safety impact on local road travel

**Piping Water**
- Takes years to build Infrastructure
- Right of Way Acquisition
- High upfront project cost
Infrastructure Costs – Pipeline
Capitol Cost for Frack Water Pipeline

- Assume a 20 mile transport 20 bbls/min

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost</th>
<th>Total Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>10” Cl. 200 PVC, G.J.</td>
<td>52800</td>
<td>LF</td>
<td>$17.00</td>
<td>$897,600</td>
</tr>
<tr>
<td>Booster Pump</td>
<td>1</td>
<td></td>
<td>$300,000.00</td>
<td>$300,000.00</td>
</tr>
<tr>
<td>Right of Way</td>
<td>20</td>
<td>MI</td>
<td>$32,000.00</td>
<td>$640,000.00</td>
</tr>
<tr>
<td><strong>TOTAL COST ESTIMATE</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$1,517,600.00</strong></td>
</tr>
</tbody>
</table>

- $1,517,600 / 80,000 bbls well frack = $18.97/bbls
**Reeves County Pipeline System**

**Gas**
- 70 miles
- 3” to 8” diameter
- 25,000 MMCF/D capacity

**Oil**
- 71 miles
- 3” to 8” diameter
- 18,000 BOPD capacity

**Salt Water Disposal**
- 65 miles
- 3” to 6” diameter
- 20,000 BWPD capacity
- 1 CWEI disposal well & 2 3rd party disposal wells
There are environmental laws and regulations currently applied to the conventional drilling and production of oil and gas. The paramount federal statutes primarily include:

- Resource, Conservation and Recovery Act (RCRA)
- Safe Drinking Water Act (SDWA).

Both became law in the 1970s, although RCRA Regulations were not promulgated until 1980, and the SWDA, as well as RCRA, are amended in proscribed intervals.
At the federal level, up until 1997, EPA did not consider fracking to fall under the purview of the Safe Drinking Water Act (SDWA). In 2004, EPA released a study that concluded the threat to drinking water was “minimal” and were still exempted from the SDWA (originally intended to regulated disposal wells).

In 2005, federal law exempted oil fracking chemicals except diesel.
In 2009, Congress considered new legislation (FRAC Act of 2009) which would amend the SDWA and allow EPA to regulate states without EPA “primacy” in underground injection control progress.

Additionally, this bill would require complete disclosure of all chemicals used in the injection fluid mix. A partial list of chemical constituents used as additives in the fracking process by the State of New York Department of Environmental Protection (NY DEC) is listed in Table 1.
Chemical disclosure in the fracking for many years was generally considered as “proprietary” by service companies, but certain chemical additives such as diesel were prohibited by federal law (Clean Water Act Amendments) in 2005.

The State of Texas recently passed a fracking bill which requires all drillers/service companies to list all chemicals and amounts used by July, 2012.
Quick Facts

Regulations:

The Texas Railroad Commission is the regulatory authority for E&P operations in the State of Texas (through Memoranda of Agreement with the Texas Commission of Environmental Quality (TCEQ)).

Permits are required to drill (W-1), as are full closure completion reports (W-2). These reports are very comprehensive, i.e. fracking information, propants used, frac water use, and other well completion information.

Permits also are required for produced water disposal (underground re-injection to non-producing zones, (disposal wells) or secondary recovery to producing zones, (injection wells).) The E&P companies may drill their own re-injection wells or use commercial wells, depending on location and economics. Right-of-way pipelines typically include dedicated oil or gas lines as well as dedicated produced water lines.
**Disposal Options**

- Underground Injection wells – UIC Class II wells
- Publicly Owned Treatment Works
- Private disposal companies
- Recycle / reuse (previously discussed)

**UIC Restrictions**

- Ohio has some of the most stringent UIC well regulations in the country.
- Arkansas prohibits UIC wells in fault zones.
- Illinois’ new law implements a “traffic light” protocol that can shut down wells if safety is at risk.
- Texas proposed HB 379 would impose a 1 cent per barrel fee on all hydraulic fracturing wastewater sent to injection wells.
New York

Moratoriums

- Revised Draft SGEIS issued in **September 2011**
  - Addresses water withdrawal, water disposal, well regulation, air quality
- Comment period closed January 11, 2012
  - DEC received **over 60,000 comments**
- Comment period for High Volume Hydraulic Fracturing Proposed Regulations closed in January 2013
- Still awaiting decision from NDEC and New York Department of Health on whether **further assessment of health impacts** from HVHF is necessary

EPA Development of Effluent Guidelines

Guidelines for Wastewater From Natural Gas Extraction

- Standards for discharges to **treatment facilities**
- Pretreatment standards for produced water
  - Requires implementation of the **best available control technologies** that are economically achievable
Global
## Energy Consumption 2009

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>U.S.(%)</th>
<th>China(%)</th>
<th>Taiwan(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>30-35</td>
<td>20</td>
<td>49 (IMPORTED)</td>
</tr>
<tr>
<td>Gas</td>
<td>25</td>
<td>3</td>
<td>7 (LNG) (IMPORTED)</td>
</tr>
<tr>
<td>Coal</td>
<td>20</td>
<td>70</td>
<td>32 (IMPORTED)</td>
</tr>
<tr>
<td>Nuclear</td>
<td>15-20</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Hydro/Geo</td>
<td>3</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Renewables</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

---

**Total primary energy consumption, in billions of metric tons of oil equivalent**

- **U.S.**
  - 2000: 2.4
  - 2009: 1.2

- **China**
  - 2000: 1.0
  - 2009: 1.2

Source: International Energy Agency
Petroleum

Fossil Fuel Exporters (oil)

Saudi Arabia is the largest exporter of petroleum in the world.

This is a list of countries by oil exports mostly based on The World Factbook.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country/Region</th>
<th>Oil - exports</th>
<th>Date of Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saudi Arabia</td>
<td>8,900,000 bbl/d (1,410,000 m³/d)</td>
<td>2007 est.</td>
</tr>
<tr>
<td>2</td>
<td>European Union</td>
<td>2,196,000 bbl/d (349,100 m³/d)</td>
<td>2001</td>
</tr>
<tr>
<td>3</td>
<td>Russia</td>
<td>5,430,000 bbl/d (863,000 m³/d)</td>
<td>2009</td>
</tr>
<tr>
<td>4</td>
<td>United Arab Emirates</td>
<td>2,540,000 bbl/d (404,000 m³/d)</td>
<td>2004 est.</td>
</tr>
<tr>
<td>5</td>
<td>Iran</td>
<td>1,500,000 bbl/d (240,000 m³/d)</td>
<td>2012 est.</td>
</tr>
<tr>
<td>6</td>
<td>Norway</td>
<td>2,500,000 bbl/d (400,000 m³/d)</td>
<td>2006 est. [2]</td>
</tr>
<tr>
<td>7</td>
<td>Canada</td>
<td>2,274,000 bbl/d (361,500 m³/d)</td>
<td>2004</td>
</tr>
<tr>
<td>8</td>
<td>Mexico</td>
<td>2,268,000 bbl/d (360,600 m³/d)</td>
<td>2004</td>
</tr>
<tr>
<td>9</td>
<td>Venezuela</td>
<td>2,203,000 bbl/d (350,200 m³/d)</td>
<td>2006 est.</td>
</tr>
<tr>
<td>10</td>
<td>Kuwait</td>
<td>2,200,000 bbl/d (350,000 m³/d)</td>
<td>2004</td>
</tr>
<tr>
<td></td>
<td>Nigeria</td>
<td>2,141,000 bbl/d (340,400 m³/d)</td>
<td>2006</td>
</tr>
</tbody>
</table>
Fossil Fuel Exporters (Natural Gas)

Russia is the largest exporter of natural gas in the world, it exports almost twice as much natural gas as the second largest exporter.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country/Region</th>
<th>Natural gas - exports (cu m)</th>
<th>Date of Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Russia</td>
<td>182,000,000,000</td>
<td>2007 est.</td>
</tr>
<tr>
<td>2</td>
<td>Canada</td>
<td>101,900,000,000</td>
<td>2005 est.</td>
</tr>
<tr>
<td>3</td>
<td>Norway</td>
<td>78,100,000,000</td>
<td>2005 est.</td>
</tr>
<tr>
<td>4</td>
<td>European Union</td>
<td>76,480,000,000</td>
<td>2005 est.</td>
</tr>
<tr>
<td>5</td>
<td>Algeria</td>
<td>62,600,000,000</td>
<td>2005 est.</td>
</tr>
<tr>
<td>6</td>
<td>Turkmenistan</td>
<td>58,000,000,000</td>
<td>2007 est.</td>
</tr>
<tr>
<td>7</td>
<td>Netherlands</td>
<td>50,210,000,000</td>
<td>2005 est.</td>
</tr>
<tr>
<td>8</td>
<td>Indonesia</td>
<td>29,600,000,000</td>
<td>2006 est.</td>
</tr>
<tr>
<td>9</td>
<td>Malaysia</td>
<td>29,060,000,000</td>
<td>2005 est.</td>
</tr>
<tr>
<td>10</td>
<td>Qatar</td>
<td>25,990,000,000</td>
<td>2005 est.</td>
</tr>
<tr>
<td></td>
<td>Trinidad and Tobago</td>
<td>21,030,000,000</td>
<td>2007 est.</td>
</tr>
</tbody>
</table>
Fossil Fuel Exporters (Coal)

This is a list of countries by coal exports mostly based on US Energy Information Administration.\[4\]

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Coal - exports (Thousand Short Tons)</th>
<th>Date of Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Australia</td>
<td>288,524</td>
<td>2009</td>
</tr>
<tr>
<td>2</td>
<td>Indonesia</td>
<td>261,419</td>
<td>2009</td>
</tr>
<tr>
<td>3</td>
<td>Russia</td>
<td>130,863</td>
<td>2009</td>
</tr>
<tr>
<td>4</td>
<td>Colombia</td>
<td>75,740</td>
<td>2009</td>
</tr>
<tr>
<td>5</td>
<td>South Africa</td>
<td>73,768</td>
<td>2009</td>
</tr>
<tr>
<td>6</td>
<td>United States</td>
<td>60,404</td>
<td>2009</td>
</tr>
<tr>
<td>7</td>
<td>China</td>
<td>38,354</td>
<td>2009</td>
</tr>
<tr>
<td>8</td>
<td>Canada</td>
<td>31,947</td>
<td>2009</td>
</tr>
<tr>
<td>9</td>
<td>Vietnam</td>
<td>28,200</td>
<td>2009</td>
</tr>
<tr>
<td>10</td>
<td>Kazakhstan</td>
<td>25,694</td>
<td>2009</td>
</tr>
<tr>
<td>COUNTRY</td>
<td>OPERATING OR IN CONSTRUCTION</td>
<td>PLANNED OR PROPOSED</td>
<td>COUNTRY</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------</td>
<td>---------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Argentina</td>
<td>3</td>
<td>3</td>
<td>North Korea DPRK</td>
</tr>
<tr>
<td>Armenia</td>
<td>1</td>
<td>1</td>
<td>South Korea ROK</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>0</td>
<td>2</td>
<td>Lithuania</td>
</tr>
<tr>
<td>Belarus</td>
<td>0</td>
<td>4</td>
<td>Malaysia</td>
</tr>
<tr>
<td>Belgium</td>
<td>7</td>
<td>0</td>
<td>Mexico</td>
</tr>
<tr>
<td>Brazil</td>
<td>3</td>
<td>4</td>
<td>Netherlands</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>2</td>
<td>1</td>
<td>Pakistan</td>
</tr>
<tr>
<td>Canada</td>
<td>19</td>
<td>5</td>
<td>Poland</td>
</tr>
<tr>
<td>Chile</td>
<td>0</td>
<td>4</td>
<td>Romania</td>
</tr>
<tr>
<td>China</td>
<td>45</td>
<td>169</td>
<td>Russia</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>6</td>
<td>3</td>
<td>Saudi Arabia</td>
</tr>
<tr>
<td>Egypt</td>
<td>0</td>
<td>2</td>
<td>Slovakia</td>
</tr>
<tr>
<td>Finland</td>
<td>5</td>
<td>2</td>
<td>Slovenia</td>
</tr>
<tr>
<td>France</td>
<td>59</td>
<td>2</td>
<td>South Africa</td>
</tr>
<tr>
<td>Germany</td>
<td>9</td>
<td>0</td>
<td>Spain</td>
</tr>
<tr>
<td>Hungary</td>
<td>4</td>
<td>2</td>
<td>Sweden</td>
</tr>
<tr>
<td>India</td>
<td>27</td>
<td>57</td>
<td>Switzerland</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0</td>
<td>6</td>
<td>Thailand</td>
</tr>
</tbody>
</table>

1 The debate about the economics of nuclear power varies strongly from country to country. The World Nuclear Association states that "Nuclear power is cost competitive with other forms of electricity generation, except where there is direct access to low-cost fossil fuels." The USA, with its coal reserves and now increasing production of shale gas, may be one of these exceptions. In many studies however, the life cycle costs of nuclear are shown to be lower than competitors. In free market economies where the large capital sums required at the outset can be difficult to raise and where the capital is at risk, financing nuclear build is difficult. In the UK, the Government has recently retreated from its hard line that no help will be provided and is now prepared to discuss "contract for difference" agreements that will assure a long-term market.
Impacts of Fukushima Decisions on Swiss Policy

<table>
<thead>
<tr>
<th>Policy pre-Fukushima</th>
<th>Post-Fukushima Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Swiss NPPs are safe</td>
<td>No new NPPs – residual risks unacceptable</td>
</tr>
<tr>
<td>CO2- ambitious reduction goals</td>
<td>Gas-fired stations to be built</td>
</tr>
<tr>
<td>Electricity supply autonomous</td>
<td>Import strategy unavoidable</td>
</tr>
<tr>
<td>Strong environmental protection laws</td>
<td>New laws to ease wind and solar permitting²</td>
</tr>
<tr>
<td>Economic production of electricity</td>
<td>Large planned increases in prices</td>
</tr>
<tr>
<td>Fair treatment of all consumers</td>
<td>Households subsidise industry</td>
</tr>
</tbody>
</table>
2013 Major Producers of Fossil Energy

1. Russia
2. Saudi Arabia
3. United States*

* Most experts expect the United States to overtake Russia and Saudi Arabia by 2017.
"It is very important that by 2019, that is three years before the Gazprom contract expires, we know how much shale we are able to produce domestically from conventional sources and, first and foremost, shale gas."
Grzyna Piotrowska-Olwa, Head of PGNiG

Poland

Recent Developments

- Poland’s shale industry is currently at an early exploratory phase. Results have not met high initial expectations.
- Poland’s resource estimates from 2011 have decreased as of 2013. The shale gas resource estimate was reduced from 187 trillion cubic feet in the 2011 report to 148 trillion cubic feet in the 2013 report.
- Threats of high taxes starting 2015 have led to many companies, such as Talisman Energy and Marathon Oil, to leave Poland, but the government has announced it will delay collection of the new tax until 2020.
Argentina

Recent Developments

- Third most technically recoverable shale gas resources and fourth most technically recoverable shale oil resources based on EIA assessed countries (2013).
- Explorations underway in the Neuquen Basin by Apache, EOG, Shell, ExxonMobil, TOTAL, YPF, and others.
- Law 26,741 (May 7, 2012):
  - Declares "self-sufficiency" of hydrocarbons as a matter of national public interest.
  - Expropriates 51% of the shares of YPF owned by Repsol.
  - Appears not to impact existing oil concessions.
  - Promotes joint ventures between YPF and private domestic and international companies.
- Recent Supreme Court decision removed an embargo on Chevron's accounts (resulting from a dispute in Ecuador), allowing Chevron to continue its venture with YPF to develop an area of the Vaca Muerta shale formation, located within the Neuquen Basin.
Stepping Ahead | Booming energy demand and lagging production boosted China's oil imports.

Economic growth spurred higher oil demand...
China's crude demand

...but domestic production couldn't keep up...
China's domestic crude production

...making China the world's No. 1 net importer of oil.

10 million barrels a day

Estimate: Sources: CNPC Economics & Technology Research Institute (demand, production); Energy Information Administration Short-Term Energy Outlook (U.S. imports, net imports); China General Administration of Customs (China imports)

The Wall Street Journal
Summary
• Virtually all new wells now are fractured. The cost ranges from 4 million to as high as 10 million dollars from spud to completion. Payout goals range from 2 to 4 years. Approximately 2 to 3 million gallons of water is required per frack, and 2,000 to 3,000 tons of proppant are required. (Proppant sand demand has risen from 10 million tons per year in 2009 to 37 million tons in 2013, nationwide.)

• Hedges (an investment position to offset potential losses/gains incurred by a companion investment) are used on occasions to protect the financial downside and cash flow of the E&P companies. For example, in the fourth quarter of 2013, a Hedge might cover 500,000 bbls of oil at a price of $100 per bbl and gas at 400,000 mmBtu at $3.50. Some companies use no Hedges while others use significant Hedges.

• Drilling and leasing activity in Texas is going up exponentially, measured by rig count and permits issued by the Texas Railroad Commission. Texas is now the tenth largest energy producer in the world. The U.S. is expected by most experts to be a net exporter of oil and gas in the next five to ten years. This is a huge impact on GDP (investments, spending, and exports-imports).
• There is a trend now to drill more horizontal fracked wells as compared to vertical.

• There is intensive interest now in Texas for developing new wells in the Wolfcamp, Permian, Eagle Ford, Barnet, and Cline Shale. For example, the Eagle Ford is currently producing over 800,000 bbls per day...even exceeding the production of the Dakotas Baakin areas. Millions of oil and gas reserves are now proven and production is expanding daily. California has extensive proven reserves (but, reluctant environmental constraints), as does the Marcellus, and there are other proven reserves in Northern Colorado and Wyoming, as well as the Midwest and eastern part of the U.S. Production continues to increase.

• Reservoir engineers are now able through seismic technologies to generally predict net yields of oil and gas per acre (TOC, formation permeability, porosity, and pay capture). This significantly increases leasing activities, lease price, and override values. It is very competitive in certain areas and becoming more so. Development and production drilling is very capital intensive, increasing farmouts, working interest, participation agreements,
joint ventures, and/or sale of master limited partnership (MLPs).

- Currently in Texas, leasing costs are up to a range of thousands of dollars per acre, depending on number of wells that can be drilled per unit area, and the number of acres one wants to lease in proven areas.

- Recently, more hydraulically fractured wells are using multiple staging and more legs in horizontal drilling (using techniques such as “zipper fracking”---alternative perforations between multiple horizontal legs).

- Most leases for a defined period of time have “drill it or lose it” provision which can be an accelerator to drill before losing or renewing a lease at a much higher cost. Such decisions require a thorough financial/cash flow analysis and expected yield, all subject to swings in oil and gas prices. This is why smaller E&P companies have to secure more debt capital from banks or bonds, find partners, and/or look to Hedging. Even in good times, it is a capital intensive and risky endeavor.
An associated but critical issue is the water resource management for continuing extraction of tight oil and gas. The use of fresh water (competing with irrigation and municipal demands) and/or reuse of treated municipal or industrial effluents, produced water, and/or flowback water are major considerations---site specific and economically driven.
Disciplines Related to Fracking of
Tight Oil and Gas

- Description of the Hydraulic Fracking Process
- Subsurface Fate and Transport, Oil and Gas
- Remediation of Frack Contaminated Water Wells
- Recovered Frack Water, Produced Water, and Mud Storage, Treatment, Reuse, and Disposal
- Redisposal or Off-Site Disposal Regulatory Issues---
  Exemptions to RCRA, and
  Pending New Legislation Triggering Non-Exempt Chemicals Under The Safe Drinking Water Act
- Litigation
- Selected Treatment and Water Reuse
- Frack Chemical Issues, Inclusion/Exclusion
- Water Demand per Produced Energy (new/reuse)
- Cost/Benefit/Risk Analysis for Fracking
- Possible Air Contamination Issues, Gas VOCs, etc.
RECENTLY COMPLETED AND PRODUCING WELL
(STILL FLARING..EXTENSIVE FORMATION GAS)
(2013)

Texas Commodities, Cattle and Oil