Onshore Programs

• Unconventional Resources
  – Resource Target
  – Approach
  – Status of selected projects

• Small Producer
  – Objective
  – Approach
  – Status of selected projects
Secure Energy for America

U. S. Technically Recoverable Gas Resource Base - Tcf

- PGC
- USGS
- Mobil
- Hubbert
- Exxon
- Hefner
- Shell
- Nehring
- DOI
- DOE
- Enron
- GTI
- AAPG
- NRC
- EIA
- NPC
- Smith & Lindsy
- Navigant

Tcf
Unconventional Gas

• Potential to Impact National, International Energy Supply
  – Abundant
  – Low carbon
  – Suitable for transportation and power generation

• Technical Challenges
  – Cost
  – Environmental impact of development
  – These challenges are closely related
Secure Energy for America

Unconventional Onshore Themes

- **Gas Shales**
  - Rock properties/Formation Evaluation
  - Fluid flow and storage
  - Stimulation
  - Water management
- **Coalbed Methane**
  - Produced water management
- **Tight Sands**
  - Natural fractures
  - Sweet spots
  - Formation Evaluation
  - Wellbore-reservoir connectivity
  - Surface footprint

Cost Reduction in All Aspects of Operations
<table>
<thead>
<tr>
<th>Area</th>
<th>CBM 10%</th>
<th>Gas Shales 45%</th>
<th>Tight Sands 45%</th>
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<tbody>
<tr>
<td>Integrated Basin Analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling</td>
<td></td>
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<tr>
<td>Stimulation and Completion</td>
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<tr>
<td>Water Management</td>
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<tr>
<td>Environmental</td>
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<td></td>
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</tr>
<tr>
<td>Reservoir Description &amp; Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reservoir Engineering</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Resource Assessment</td>
<td></td>
<td></td>
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<tr>
<td>Exploration Technologies</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Priority Level</th>
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<tr>
<td>H</td>
</tr>
<tr>
<td>M</td>
</tr>
<tr>
<td>L</td>
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</table>

Total Cost to RPSEA
<table>
<thead>
<tr>
<th>Category</th>
<th>CBM 10%</th>
<th>Gas Shales 45%</th>
<th>Tight Sands 45%</th>
<th>Total</th>
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<tbody>
<tr>
<td>Integrated Basin Analysis</td>
<td></td>
<td>New Albany (GTI) $3.4</td>
<td>Piceance (CSM) $2.9</td>
<td>$6.3</td>
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<tr>
<td>Drilling</td>
<td></td>
<td></td>
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<td>$0.0</td>
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<tr>
<td>Stimulation and Completion</td>
<td>Microwave CBM (Penn) $.08</td>
<td>Cutters (Carter) $.09</td>
<td>Gel Damage (TEES) $1.05</td>
<td>$4.7</td>
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<tr>
<td>Water Management</td>
<td>Integrated Treatment Framework (CSM) $1.56</td>
<td>Barnett &amp; Appalachian (GTI) $2.5</td>
<td>Frac Water Reuse (GE) $1.1</td>
<td>$5.2</td>
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<td>Environmental</td>
<td>Environmentally Friendly Drilling (HARC) * $2.2</td>
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<td>$2.2</td>
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<td>Reservoir Description &amp; Management</td>
<td>Hi Res. Imag. (LBNL) $1.1</td>
<td>Tight Gas Exp. System (LBNL) $1.7</td>
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<td>$5.1</td>
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<tr>
<td>Reservoir Engineering</td>
<td>Gas Isotope (Caltech) $1.2</td>
<td>Strat. Controls on Perm. (CSM) $0.1</td>
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<td></td>
<td>Marcellus Nat. Frac./Stress. (BEG) $1.0</td>
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<td></td>
<td>Decision Model (TEES) $.31</td>
<td>Wamsutter (Tulsa) $.44</td>
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<td>Resource Assessment</td>
<td>Coupled Analysis (LBNL) $2.9</td>
<td>Forecasting (Utah) $1.1</td>
<td>Condensate (Stanford) $.52</td>
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<td>Coal &amp; Bugs (CSM) $.86</td>
<td>Alabama Shales (AL GS) $.5</td>
<td>Rockies Gas Comp. (CSM) $.67</td>
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<td></td>
<td>Multi-Azimuth Seismic (BEG) $1.1</td>
<td>Manning Shales (UT GS) $.43</td>
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<td>2008 Projects</td>
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<tr>
<td></td>
<td>L Low Priority</td>
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</tbody>
</table>
RPSEA Unconventional Gas Projects

Cross-Cutting Technical Projects 2007
- UT – Fracturing
- LBNL – Self Teaching Expert System
- UT – Refracturing
- TAMU – Fracture Design
- TAMU – Decision Model
- LBNL – High Resolution Imaging
- PSU – Microwave Coals
- Carter – Saws
- U of Tulsa – Novel Fracturing Fluids
- Stanford – Condensate

2007 Technical/Resource Projects
- Anchor Projects - Integrated Basin Analysis
- CSM - Coal Bugs
- Utah GS - Paleozoic Shales
- U of Tulsa – Wamsutter
- CSM – Gas Composition
- U of Utah – TGS
- CSM – Produced Wtr.
- CSM – Piceance TGS
- CSM – Strat Control

2008 Technical/Resource Projects
- Anchor Projects - Integrated Basin Analysis
- Cross-Cutting Technical Projects 2008
- HARC – Environmentally Friendly Drilling
- LBNL – Coupled Reservoir Model
- TAMU – Fracture Conductivity
- BEG – Multi – Azimuth Seismic
- Caltech – Gas Isotopes

$32 Million Research Portfolio
## Significant Producer and Service Industry Involvement
- Crucial for Program Relevancy

<table>
<thead>
<tr>
<th>Producers</th>
<th>Service Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anadarko</td>
<td>Devon Energy</td>
</tr>
<tr>
<td>Chevron</td>
<td>Unconventional Gas Resources Canada</td>
</tr>
<tr>
<td>Pioneer Natural Resources</td>
<td>Whiting Petroleum</td>
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<tr>
<td>Williams E&amp;P</td>
<td>CNX Gas</td>
</tr>
<tr>
<td>ConocoPhillips</td>
<td>Trendwell</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>Diversified Operating Corp</td>
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<td>Newfield Exploration</td>
<td>Noble Energy</td>
</tr>
<tr>
<td>NGAS</td>
<td>Jones Energy</td>
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<tr>
<td>Encana</td>
<td>Aurora Oil &amp; Gas</td>
</tr>
<tr>
<td>BP</td>
<td>Schlumberger</td>
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<tr>
<td>Bill Barrett Corp.</td>
<td>Halliburton</td>
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<tr>
<td>Pinnacle Gas Resources</td>
<td>Pinnacle Technologies</td>
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<tr>
<td>Coleman Oil &amp; Gas</td>
<td>BJ Services</td>
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<tr>
<td>Ciris Energy</td>
<td>Carbo Ceramics</td>
</tr>
</tbody>
</table>

Secure Energy for America
Project Highlights

Unconventional Onshore Program
Shale Resource Assessment

• Alabama – Geological Survey of Alabama
  – Neal (Floyd) Shale, Conasauga Formation, Devonian Shale
  – Each have technical challenges/how to address?
  – See Spring 2009 NETL “E&P Focus”

• Utah – Utah Geologic Survey
  – Manning Canyon, Delle Phosphatic, Paradox Shale resources
  – Evaluate potential
  – Requirements for economic production
Paleozoic Shale-Gas Resources of the Colorado Plateau and Eastern Great Basin, Utah: Multiple Frontier Exploration Opportunities – Utah Geologic Survey

**Project Goal**

Provide basin specific analyses of shale-gas reservoir properties to develop the best local completion practices that can be applied to the emerging Manning Canyon, Delle Phosphatic, and Paradox frontier gas shales.

**Objectives**

- Identify and map the major trends for frontier gas shale
- Identify areas with the greatest gas potential
- Characterize the geologic, geochemical, petrophysical, & geomechanical rock properties
- Reduce exploration costs & drilling risk especially in environmentally sensitive areas
- Recommend the best practices to complete & stimulate frontier gas shales to reduce development costs & maximize gas recovery
# Timing and Major Milestones

<table>
<thead>
<tr>
<th>Technical Tasks</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
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<tr>
<td></td>
<td>Q3</td>
<td>Q4</td>
<td>Q1</td>
<td>Q2</td>
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<tr>
<td>Task 1.0. Project Management Plan</td>
<td>●</td>
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<tr>
<td>Task 2.0. Technology Status Assessment</td>
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<tr>
<td>Task 3.0. Technology Transfer</td>
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## Phase I

<table>
<thead>
<tr>
<th>Technical Tasks</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
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<td></td>
<td>Q3</td>
<td>Q4</td>
<td>Q1</td>
<td>Q2</td>
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<td>Task 4.0: Data Compilation.</td>
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<td>Task 5.0: Core and Cuttings Examination and Sample Analysis</td>
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<td>Task 6.0: Outcrop Examination and Sample Analyses</td>
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## Phase II

<table>
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<tr>
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<th>2011</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Q3</td>
<td>Q4</td>
<td>Q1</td>
<td>Q2</td>
</tr>
<tr>
<td>Task 7.0: Determination of Best Completion Practices</td>
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<td>Task 8.0: Regional Correlation, Mapping, and Depositional History Determination</td>
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<tr>
<td>Task 9.0: Final Interpretations and Recommendations</td>
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<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>
Technical Advisory Board

- Shell E & P Company
- Sinclair Oil and Gas Company
- Encana Oil and Gas USA, Inc.
- Bill Barrett Corporation
- CrownQuest Operating, LLC
- ST Oil Company
Tech Transfer

- Two presentations at AAPG, June 2009
  - Shale Gas and Shale Oil Resources of the Paradox Basin, Colorado and Utah, by Steve Schamel
  - Gas Shale Characteristics from the Pennsylvanian of Southeastern Utah, USA, by S. Robert Bereskin and John McLennan
How Does Gas Migrate into and Fill Unconventional Reservoirs?

Different Mechanisms Should Leave Different Signatures in the Gas Composition; Assisting with Exploration Strategy

- Gas pressure Produces Fractures
- Gas Diffuses Through Seals
- Gas Migrates Along Faults
Progress to date:

Technology status document submitted.

Project website is online, with resources for the general public.

Analysis of gas samples – underway.

- Initial set of bulk gas and compound-specific isotopic analyses – complete.

Migration modeling – underway

- Training in MPath is complete.
- Ph.D. student now developing a preliminary migration model for Jonah Field.
Summary:

• Scientific model is valid ... so far.

• Research approach is workable ... so far.

• Progress depends on developing a substantial database
  - This will require a major field effort from June – September and additional manpower (grad student + field assistant).

• Good cooperation from companies and attracting continuing industry interest
  - One additional company (Marathon) signed up.
Identification of Refracturing Opportunities

- Methodology for candidate well selection based on poro-elastic models and analysis of field data.
- Recommendations for the time window most suitable for re-fracturing
- Re-fracture treatment design for horizontal and deviated wellbores

Stress Profile Created by Horizontal Producing Well

University of Texas
Objectives

- Use principal component analysis to determine the increase in production rate after a refracture treatment.
- Use stress reorientation models to study the role played by stress reorientation vs other factors such as GOR and depletion.
- Use these findings to recommend timing for refracs
- Create a statistical, predictive model for
  - Production enhancement
  - Candidate well selection
Selecting Timing and Candidate Wells for Re-fracturing

\[ \lambda_{\text{max}} = 4.13 \text{ years} \]

\[ \tau_{\text{max}} = 1.15 \text{ months} \]

\[ \tau_{\text{max}} = 1.3 \text{ days} \]

Optimum time for refracturing

Time (months)

Maximum areal extent of stress reversal

- Shale
- Tight Gas
- Sandstone
Summary of Progress to Date

- Stress reorientation due to poroelastic effects has been calculated for vertical, fractured and horizontal wells.
- Key parameters and conditions that control this stress reorientation have been identified.
- The optimum timing of refrac treatments has been computed for the first time.
- A data set of refrac treatments from the Wattenburg field has been reviewed and is being analyzed for statistical trends.
- Review of refrac treatment designs in progress.
Unconventional Resources Program

• All Projects Reviewed with PAC, April 2009
  – Critical review by PAC
  – Review by PI Group
  – Communication among PIs
  – Identify opportunities for cooperation
  – Provide direction for draft Annual Plan
The Technology Challenges of Small Producers

Focus Area – Advancing Technology for Mature Fields

- Target – Existing/Mature Oil & Gas Accumulations
  - Maximize the value of small producers’ existing asset base
  - Leverage existing infrastructure
  - Return to production of older assets
  - Minimal additional surface impact
  - Minimize and reduce the existing environmental impact

- Lower cost and maximize production
7 Small Producer Projects Funded in 2007

- Cost Effective Treatment of Produced Water Using Co-Produced Energy Sources for Small Producers
- Enhancing Oil Recovery from Mature Reservoirs Using Laterals and High-volume Progressive Cavity Pumps
- Reducing Impacts of New Pit Rules on Small Producers
- Field Site Testing of Low Impact Oil Field Access Roads: Reducing the Footprint in Desert Ecosystems
- Near Miscible CO₂ Application to Improved Oil Recovery for Small Producers
- Preformed Particle Gel for Conformance Control
- Seismic Stimulation to Enhance Oil Recovery
Field Site Testing of Low Impact Oil Field Access Roads: Reducing the Footprint in Desert Ecosystems

Project Leader: Texas A&M University
Additional Project Participants: Rio Vista Bluff Ranch and Halliburton

The Problem:
Intensive development within existing fields requires more infrastructure and road-building. This can increase costs, regulatory requirements, and environmental impacts.

Project Goals:
• Create an industry desert test center where new technology can be evaluated under controlled conditions in a field environment
• Build a test track simulating a minimal impact O&G lease road
• Analyze the performance of various products used in test sections and perform an economic analysis to measure applicability of the alternate systems
Field Site Testing of Low Impact Oil Field Access Roads: Reducing the Footprint in Desert Ecosystems

Web site has been established at http://sites.google.com/a/pe.tamu.edu/low-impact-access/Home/low-impact-access-roads-demonstration

A test road location has been selected, and a detailed schedule has been prepared.

Road sections will be laid out alongside but offset from the existing gravel track because we want to see how the test sections will work on unprepared soil and ultimately how easily they can be remediated.

The Pecos Research and Testing Center is located Southeast of Pecos Texas, approximately 1.5 hour drive from the Midland/Odessa airport.
Cost Effective Treatment of Produced Water Using Co-Produced Energy Sources for Small Producers

Approach:

1. Process has been optimized for enhanced water recovery and energy efficiency

2. Researchers have designed the optimized process for demonstration

3. Produced water direct heating by solar energy has been designed

4. On-going work includes equipment procurement and on site preparation for demonstration
<table>
<thead>
<tr>
<th>Composition</th>
<th>Feed water</th>
<th>Purified water</th>
<th>Removal efficiency, %</th>
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<tbody>
<tr>
<td>Total dissolved solid (TDS), mg/L</td>
<td>19756.0</td>
<td>76.35</td>
<td>99.6</td>
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<tr>
<td>Total suspended particulates, mg/L (0.22μm &lt; dia. &lt; 100μm)</td>
<td>99.6</td>
<td>Undetectable</td>
<td>100%</td>
</tr>
<tr>
<td>Total organic carbon (TOC), mg/L</td>
<td>470.2</td>
<td>17.83</td>
<td>96.2%</td>
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</table>
# 2008 Small Producer Project Selections

## Reservoir Characterization

<table>
<thead>
<tr>
<th>Lead Organization</th>
<th>Title</th>
<th>Partners</th>
<th>Main region</th>
<th>Total Cost</th>
<th>Cost Share</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>University of Texas of the Permian Basin</td>
<td>Commercial Exploitation and the Origin of Residual Oil Zones: Developing a Case History in the Permian Basin of New Mexico and West Texas</td>
<td>Chevron, Legado Resources, Yates Petroleum</td>
<td>Permian Basin</td>
<td>$962,251</td>
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<tr>
<td>Western Michigan University</td>
<td>Evaluation and Modeling of Stratigraphic Control on the Distribution of Hydrothermal Dolomite Reservoir away from Major Fault Planes</td>
<td>Polaris Energy Company</td>
<td>Michigan</td>
<td>$1,138,864</td>
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<tr>
<td>UT Austin - Bureau of Economic Geology</td>
<td>Development Strategies for Maximizing East Texas Oil Field Production</td>
<td>Danmark Energy, John Linder Operating</td>
<td>Texas</td>
<td>$1,969,890</td>
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## 2008 Small Producer Project Selections

### Oil and Gas Recovery

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<th>Duration</th>
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<tbody>
<tr>
<td>New Mexico Institute of Mining and Technology</td>
<td>Mini-Waterflood: A New Cost Effective Approach to Extend the Economic Life of Small, Mature Oil Reservoirs</td>
<td>Armstrong Energy</td>
<td>Southwest</td>
<td>$1,107,659</td>
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<td>Layline Petroleum 1, LLC</td>
<td>Field Demonstration Of Alkaline Surfactant Polymer Floods In Mature Oil Reservoirs Brookshire Dome, Texas</td>
<td>Tiorco, University of Texas at Austin</td>
<td>Mid-Continent</td>
<td>$1,226,396</td>
<td>51</td>
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# 2008 Small Producer Project Selections

**Utilizing Waste to Increase Efficiency**

<table>
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<tr>
<th>Lead Organization</th>
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<th>Partners</th>
<th>Main region</th>
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<th>Duration</th>
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