Shale Projects Becoming Globally Important
U.S. Shale Oil & Gas Experience Extrapolates Globally
Global Shale Gas Estimated Reserves

Gas reserves* (Trn cubic metres)
2011 or latest available

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves</th>
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<tbody>
<tr>
<td>CANADA</td>
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<tr>
<td></td>
<td>11.0</td>
</tr>
<tr>
<td>UNITED STATES</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>24.4</td>
</tr>
<tr>
<td>POLAND</td>
<td>0.2</td>
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<tr>
<td></td>
<td>5.3</td>
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<tr>
<td>RUSSIA</td>
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<td>CHINA</td>
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<td></td>
<td>36.1</td>
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<tr>
<td>QATAR</td>
<td>25.4</td>
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<tr>
<td>ARGENTINA</td>
<td>0.4</td>
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<td>SOUTH AFRICA</td>
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<tr>
<td>AUSTRALIA</td>
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</tr>
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<td></td>
<td>11.2</td>
</tr>
</tbody>
</table>

Sources: US Energy Information Administration; The Economist

*Selected countries
Shale Projects are Going Global

Potential projects are developing momentum

Source: EIA
Shale projects: Project Execution

**Predict**
- Determine Reserves and Productivity
  - Core and Core Analysis
  - Mud Logging
  - Wireline Logging
  - Reservoir Evaluation
  - Exploration Plan

**Pilot**
- Optimize for Execution
  - Finalize Field Development Plan
  - Drilling
  - Completion Type
  - Production Testing
  - Development Plan

**Produce**
- Increase well construction efficiency and maximize production
  - Drilling / Directional
  - Completion / Stimulation
  - Lift / Optimization

Go/No Go point $
Unconventional Plays > Leading Edge Services

- Wireline / Perforating
- Pump down plugs
- Wellhead Systems
- Frac flow back & testing
- Water Treatment Systems
- Coiled Tubing
- Frac Stacks
- Multi zone completion systems
- Drilling rental tools

Operating Company

Fracturing
Geo Sciences
MWD & Drilling
Operator Challenges for Shale Plays

- Accurate characterization of the shale reservoir in vertical wells
  - Laboratories / Wireline / Surface Logging Systems

- Optimal wellbore placement in horizontal wells – geo-steering the “sweet spot”
  - Logging While Drilling (LWD) / Surface Logging Systems

- Optimal frac design and stage placement along the horizontal wellbore
  - Stimulation / Completions / Micro-seismic
Good Science Leads to Good Engineering

Reservoir Information
- Thickness
- Organic richness
- Maturation
- Gas-in-place
- Pore pressure
- Permeability
- Recovery Factor
- Brittleness
- Mineralogy
- Continuity

Source: Colorado School of Mines

Geosciences

- Mud Logging
- Micro-seismic
- Geo Chemistry
- Geo Mechanics
- Formation Evaluation
- Core Analysis

Integrating datasets with interpretive expertise to enable low risk decisions
Directional Planning a Shale Well

Horizontal wells begin with a wellbore plan.
Pad Drilling in Environmentally Sensitive Areas

MWD / LWD / RSS

Image courtesy Statoil/Hydro
Drilling Direction – Critical to Stimulation

- $\sigma_{H_{\text{max}}}$
- $\sigma_{H_{\text{min}}}$
- Openhole
- Spiral perforations
Integrated Drilling Services

- Mud Logging Services
- Wellsite Lab Cuttings Analysis
  - SRA, XRf/XRd, TOC,
  - Thermal Maturity, $R_0$
- Directional Drilling
- MWD
- LWD
  - GR, SAGR, MFR,
  - Neutron/Density, Sonic
Most US Shale operators favor RSS

Rotary Steerable System

- Increase Bore hole quality and overall ROP in a directionally controlled well.
- Increases the length of lateral sections by reducing the amount of torque and drag created by sliding a conventional drilling motor assembly.
- Enables a Directional Well Bore to be drilled without sliding reducing drilling time and costs.
## Hydraulic Fracturing

### Horse Power Requirements

<table>
<thead>
<tr>
<th>Formation</th>
<th>Avg. HHP / Fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haynesville</td>
<td>54,000 HHP / Fracture</td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>54,000 HHP / Fracture</td>
</tr>
<tr>
<td>Marcellus</td>
<td>30,000 HHP / Fracture</td>
</tr>
<tr>
<td>Barnett</td>
<td>24,000 HHP / Fracture</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>28,000 HHP / Fracture</td>
</tr>
<tr>
<td>Woodford</td>
<td>25,000 HHP / Fracture</td>
</tr>
</tbody>
</table>

### Volume Requirements

<table>
<thead>
<tr>
<th>Formation</th>
<th>Lbs / bbls. H₂O (Stages/well)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haynesville</td>
<td>7,470K lbs / 150K bbls. H₂O (18 Stages/well)</td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>6,000K lbs / 120K bbls. H₂O (15 Stages/well)</td>
</tr>
<tr>
<td>Marcellus</td>
<td>3,000K lbs / 120K bbls. H₂O (10 Stages/well)</td>
</tr>
<tr>
<td>Barnett</td>
<td>3,200K lbs / 95K bbls. H₂O (8 Stages/well)</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>4,000K lbs / 110K bbls. H₂O (10 Stages/well)</td>
</tr>
<tr>
<td>Woodford</td>
<td>3,250K lbs / 95K bbls. H₂O (13 Stages/well)</td>
</tr>
</tbody>
</table>
On the Job Monitoring is Critical

Real Time & Engineering Tools

Real Time Monitoring
- Control Pumps (to vary pump rate on the fly)
- Blenders (to vary prop concentration on the fly)
- Hydration Units (to vary chemicals as needed)

Engineering Station
- To run stimulation Software
- Monitor fracture critical parameters
- Make engineering decisions on the fly

Real-time Capability
- Transmit Data Via Satellite Link
- Fracture Analysis
- Replay Monitoring Plots On Multiple Monitors
- Step Rate & Mini-Frac Analysis
- Pump In-Flow Back
- Pressure Decline
Plug and Perf. Method for Horizontal Wells

Pump Down Services

• Dedicated assets for on location for Pump Down Services
  – Optimizes timing

• Integration of plugs/adapter kits
  – Minimizes failures

• Proven communication with Fracturing Services crew
  – Critical to optimize time

Single trip set plug and perforate
Multi-Zone Completion Systems

ZoneSelect™ Weatherford’s modular system for selective isolation and stimulation of openhole completions

Sleeve Options
- Toe Sleeve
- Multi-Shift Sleeve
- Monobore Sleeve
- Single Shot Sleeve

Packer Options
- Liner Hanger/Packer
- Bulldog HD
- Genesis Swellable Packer
- Fraxis Swellable Packer

Accessory Tool
- Port Collar
- Rok ANkOR
- Horizontal Ball Seat
The milling out of the frac plugs or completion becomes a critical operation.

Coiled Tubing should be used for this operations as it has the capability to:
- Continually drill
- Minimize the damage
- Minimize time
Well Testing and Flowback Services

Frac Flow Back

A complete frac flowback package should be used after each well is completed

- Flow lines
- Manual & Hydraulic Choke Manifolds
- Pressurized proppant/sand knockout vessels
- Three & four phase test separators
- Tankage to Manage Proppant Returns
- In-Line/Closed Loop Testing and Pipe Cleaning/Dewatering

Controlled flowback/cleanup operations before entering the production lines and facilities is the key to optimizing the well performance after all operations are completed.
Micro-Seismic Services

- Well Site fracture mapping can be beneficial to:
  - Evaluation of the fracture evolution in real time and take appropriate steps to optimize the stage
- Off the Well Site fracture mapping can
  - Reveal anomalous drainage patterns
  - Wellbore interference
  - Inefficient completion designs
## Shale Development Challenges

<table>
<thead>
<tr>
<th>Drilling</th>
<th>Evaluation</th>
<th>Completion</th>
<th>Production</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do I cut well costs to make these wells more economic?</td>
<td>How do I know where to place my wells?</td>
<td>How do I maximize fracture conductivity?</td>
<td>How can I determine if my hydraulic fracs are successful?</td>
<td>How can life-of-well interventions be accomplished cost effectively?</td>
</tr>
<tr>
<td>How do I manage gas/oil shale differences?</td>
<td>How can I integrate multiple datasets to make better decision?</td>
<td>How do I achieve the most effective multi-zone frac stimulation?</td>
<td>What methods can I use to initiate the frac flowback process?</td>
<td>How can I re-enter depleted wells and rejuvenate production?</td>
</tr>
<tr>
<td>How do we ensure we are geo-steering effectively?</td>
<td>Can I get high quality open hole logs in long horizontal wellbores?</td>
<td>Which is better – an open hole or cased hole completion?</td>
<td>Is there a method to recover frac fluids in a more environmentally safe manner?</td>
<td>At what point in the life of the well do I consider re-fracturing?</td>
</tr>
<tr>
<td>How can I drill the build section and lateral more quickly?</td>
<td>What about shale sweet spot identification?</td>
<td>Should I consider switching to a hybrid frac design?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Frac locations can be busy places
Service Companies Are Logical Too

Integrating Seismic > Steering > Stimulation > Production Optimization

Visualize
- 2-D & 3-D Seismic
- Basin Data
- Full Core
- OH Logs
- Offset Logs

Earth Model

Position
- Geo-Steering Model
- MWD/LWD Logging Data
- Wellsite Geochemistry
- Azimuthal/Spectral LWD
- Image & specialty logs
- Offset Info
- Bit Records
- Mud Records

Geo-Mechanics Model

Production Prediction Model

The Future

Complete
- Stimulation Model
- Micro-Seismic/Tiltmeter
- Sonic Anisotropy Logs
- Production Logging Data
- Tracer Log Data

Produce

Use Data to Revise Models

Software
- Petrel
- Abacus
- LogXD
- STABView
- FracPro
- Eclipse
- S2S
- WellFlo
- LOWIS
Integrated Services - Benefits

- Improved Safety
- Ensures Resources are Available
- Simplified Pricing
- NPT risk transferred to Service Company
- Increased Completion Efficiency
- Quality Assurance
- On-Site Coordinator
Water is a Major Consideration in Shale wells

Substantially Larger Volumes
4-6 million gallons per well
Increased Pump Rates
80-100 bpm