The U.S. Shale Revolution: Certainty in an Uncertain World

Presentation to:
CCUS Student Week 2018

By:
John Harpole

October 16, 2018
The New “Metaphor” by Maytag
Don’t worry about your future in the energy industry.

“If we didn’t have oil, we would invent it.”

- Robert Bryce

Lesson: Don’t ever think that the renewable energy industry is going to put you out of a job. It is all about energy density.

“... an all-renewable California would need more solar capacity in the state than currently exists on the entire planet.”*

Source: http://robertbryce.com/all-renewable-energy-in-california/
Preface

In order to meet California’s 100% renewable energy target by 2045, the wind energy contribution to that goal would require that “California would have to cover a land area roughly four times the size of L.A. County with nothing but massive windmills.”

It is all about energy density and don’t forget it.

Source: http://robertbryce.com/all-renewable-energy-in-california/
Preface

"According to the EIA, in 1949, oil provided 37 percent of America’s total energy needs. In 2009, oil’s share of U.S. primary energy stood at ... 37 percent."

"Here’s the bottom line: Renewables will remain niche players in the global energy mix for decades to come. The past—and the foreseeable future—still belong to hydrocarbons. And we can expect natural gas, the cleanest of the hydrocarbons, to garner a bigger share of the global energy pie in the near term and in the long term."

Source: Don’t Count Oil Out, Robert Bryce, October 2011
It is not a scarce resource anymore

Source: US Energy Information Administration
Circa 2007

Russia’s Energy Muscle

- Energy Used Over 55 times Against Former Soviet Nations Since 1990

Source: Europe Doubles Down on Russian Gas to Feed its Energy Appetite, by Andrew Haney, Ricardo Bracho, Nick Wolfe and Max Faith
Circa 2007

Gazprom’s Current Near-Monopoly Supply Position

<table>
<thead>
<tr>
<th>Country</th>
<th>% of Supply from Gazprom/Russia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slovakia</td>
<td>100%</td>
</tr>
<tr>
<td>Macedonia</td>
<td>100%</td>
</tr>
<tr>
<td>Finland</td>
<td>99%</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>97%</td>
</tr>
<tr>
<td>Serbia &amp; Montenegro</td>
<td>87%</td>
</tr>
<tr>
<td>Lithuania*</td>
<td>84%</td>
</tr>
<tr>
<td>Hungary</td>
<td>80%</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>79%</td>
</tr>
<tr>
<td>Greece</td>
<td>76%</td>
</tr>
</tbody>
</table>

*Remember

Circa 2007

Gazprom’s Current Near-Monopoly Supply Position
(cont’d)

<table>
<thead>
<tr>
<th>Country</th>
<th>% of Supply from Gazprom/Russia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>74%</td>
</tr>
<tr>
<td>Slovenia</td>
<td>64%</td>
</tr>
<tr>
<td>Poland</td>
<td>62%</td>
</tr>
<tr>
<td>Turkey</td>
<td>60%</td>
</tr>
<tr>
<td>Germany</td>
<td>40%</td>
</tr>
<tr>
<td>Croatia</td>
<td>37%</td>
</tr>
<tr>
<td>Italy</td>
<td>30%</td>
</tr>
<tr>
<td>Romania</td>
<td>28%</td>
</tr>
<tr>
<td>France</td>
<td>25%</td>
</tr>
</tbody>
</table>

10/21/2008 in Tehran, Iran
Russia, Iran and Qatar form natural gas cartel

Qatar’s Deputy Premier and Minister of Energy and Industry, Abdullah bin Hamad Al-Attiya

Iranian Oil Minister, Gholam Hossein Nozari

Alexei Miller, Chief of Russia’s state gas monopoly - Gazprom
Circa 2007

U.S. Shale Gas Development Could be Slowed by LNG Imports

• “Importing LNG to the U.S. would be economical at an average gas price as low as $3.50/MMBtu.”

• “Whereas shale gas requires an average gas price of at least $6.50/MMBtu to be economical.”

Source: Scott Thetford, VP of Pace Global Energy Services, LLC
Wrong!
... and then the U.S. Shale Revolution happened... and the world will never be the same again.
US Crude Oil Production, January 1986 to December 2014

Source: Energy Information Administration

Source: My top ten energy charts of the year for 2014, Mark J. Perry, American Enterprise Institute, January 5, 2015
Daily Oil Production: Permian Basin, Eagle Ford and Bakken
January 2007 to January 2015 (est.)

Source: Energy Information Administration

Permian Basin
Eagle Ford
Bakken

Barrels/day
2,000,000
1,600,000
1,200,000
800,000
400,000
0

Source: My top ten energy charts of the year for 2014, Mark J. Perry, American Enterprise Institute, January 5, 2015
Total Petroleum Production: Saudi Arabia vs. US January 1994 to September 2014

Source: Energy Information Administration

Source: My top ten energy charts of the year for 2014, Mark J. Perry, American Enterprise Institute, January 5, 2015
U.S. Crude Oil Imports

FIGURE 3
UNITED STATES NATURAL GAS PRODUCTION

Billion Cubic Feet Per Day

Price Controls
Section 29 Tax Credits

Lower 48
Conventional (Non-Associated)

Gulf of Mexico

Tight

Shale

Associated

Coalbed

Source: The Outlook for Oil and Gas, Henry Groppe, Groppe, Long & Littell, May 2017
Production of Crude Oil and Natural Gas

Oil and Gas Production Added Per Rig

Spud to Total Depth in Less than Three Days

Source: *US Shalers – Beating the Bears*, Trisha Curtis, PetroNerds, presentation to The Oxford Institute for Energy Studies, November 2017
Shale Oil Play Production

4.9 mbd – over half of US production (9.2 md)

Permian – 2.4 mbd
Eagle Ford -1 mbd
Williston – 1 mbd
DJ – 340,000 b/d
Powder – 91,000 b/d

Source: PetroNerds, DrillingInfo

Source: US Shalers – Beating the Bears, Trisha Curtis, PetroNerds, presentation to The Oxford Institute for Energy Studies, November 2017
Permian Basin Productivity by Average Lateral Length

Source: US Shalers – Beating the Bears, Trisha Curtis, PetroNerds, presentation to The Oxford Institute for Energy Studies, November 2017
Permian Basin Productivity by Average Lateral Length

Source: US Shalers – Beating the Bears, Trisha Curtis, PetroNerds, presentation to The Oxford Institute for Energy Studies, November 2017
Fracturing Application Exploded

North American Frac Horsepower

Source: Chris Wright, Liberty Resources Tuesday Lunch Club Presentation, 3/5/13
10-fold growth in 10 years

Source: Chris Wright, Liberty Resources Tuesday Lunch Club Presentation, 3/5/13
The House of Saud’s Motivation

2009-2014 Global Liquids Supply Growth Breakdown (MMbpd)

Supply Growth (09-14): 8.06 MMbpd

- US Liquids, 4.42 MMbpd (55%)
- OPEC Oil, 1.55 MMbpd (19%)
- OPEC NGLs, 1.74 MMbpd (22%)
- Non-OPEC, Ex-US Supply, -0.07 MMbpd (-1%)
- Other*, 0.41 MMbpd (5%)

Source: IEA, Raymond James research
*Includes processing gains and biofuels

"In 2016, when OPEC completes this objective of cleaning up the American marginal market, the oil price will start growing again," said Fedun, who’s made a fortune of more than $4 billion in the oil business, according to data compiled by Bloomberg. “The shale boom is on a par with the dot-com boom. The strong players will remain, the weak ones will vanish.”

- Leonid Fedun, VP and Board Member at OAO Lukoil (LKOD)
“The reason, according to Iranian Oil Minister, Bijan Namdar Zanganeh, was to keep prices low enough and long enough to threaten the U.S. shale oil industry and restore OPEC’s market share in America. Shale extraction requires expensive methods such as fracking and horizontal drilling, and many observers say it isn’t profitable if the price of oil drops below $65 per barrel.”

Source: Real Money, The Street Ratings, By: Oilprice.com, December 11, 2014
OPEC Secretary Urging US Shalers to Slow it Down – Oct 9, 2017

Source: US Shalers – Beating the Bears, Trisha Curtis, PetroNerds, presentation to The Oxford Institute for Energy Studies, November 2017
OPEC Secretary Urging US Shalers to Slow it Down – Oct 9, 2017

“We urge our friends, in the shale basins of North America to take this shared responsibility with all seriousness it deserves, as one of the key lessons learnt from the current unique supply-driven cycle,” said Barkindo.

Source: US Shalers – Beating the Bears, Trisha Curtis, PetroNerds, presentation to The Oxford Institute for Energy Studies, November 2017
# OPEC Member States

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>Africa</td>
<td>1969</td>
<td>33,779,668</td>
<td>2,381,740</td>
</tr>
<tr>
<td>Angola</td>
<td>Africa</td>
<td>2007</td>
<td>12,531,357</td>
<td>1,246,700</td>
</tr>
<tr>
<td>Iran</td>
<td>Middle East</td>
<td>1960[A 2]</td>
<td>75,875,224</td>
<td>1,648,000</td>
</tr>
<tr>
<td>Iraq</td>
<td>Middle East</td>
<td>1960[A 2]</td>
<td>28,221,180</td>
<td>437,072</td>
</tr>
<tr>
<td>Kuwait</td>
<td>Middle East</td>
<td>1960[A 2]</td>
<td>2,596,799</td>
<td>17,820</td>
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<tr>
<td>Libya</td>
<td>Africa</td>
<td>1962</td>
<td>6,173,579</td>
<td>1,759,540</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Africa</td>
<td>1971</td>
<td>146,255,300</td>
<td>923,768</td>
</tr>
<tr>
<td>Qatar</td>
<td>Middle East</td>
<td>1961</td>
<td>824,789</td>
<td>11,437</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>Middle East</td>
<td>1960[A 2]</td>
<td>28,146,656</td>
<td>2,149,690</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>Middle East</td>
<td>1967</td>
<td>4,621,399</td>
<td>83,600</td>
</tr>
<tr>
<td>Venezuela</td>
<td>South America</td>
<td>1960[A 2]</td>
<td>26,414,816</td>
<td>912,050</td>
</tr>
</tbody>
</table>

| Total               |                 | 369,368,429    | 11,854,977 km²           |
Survival of the Fittest?

*Circa 2014: Saudis have staying power; $750 billion in foreign country reserves

## A Game of Chicken?

<table>
<thead>
<tr>
<th>Nation</th>
<th>Oil price per barrel required to break even or balance budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>US producers</td>
<td>$38-$77</td>
</tr>
<tr>
<td>Qatar</td>
<td>$58</td>
</tr>
<tr>
<td>Kuwait</td>
<td>$59</td>
</tr>
<tr>
<td>UAE</td>
<td>$90</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>$92</td>
</tr>
<tr>
<td>Angola</td>
<td>$94</td>
</tr>
<tr>
<td>Russia</td>
<td>$101</td>
</tr>
<tr>
<td>Iraq</td>
<td>$116</td>
</tr>
<tr>
<td>Venezuela</td>
<td>$117</td>
</tr>
<tr>
<td>Algeria</td>
<td>$119</td>
</tr>
<tr>
<td>Ecuador</td>
<td>$122</td>
</tr>
<tr>
<td>Nigeria</td>
<td>$124</td>
</tr>
<tr>
<td>Iran</td>
<td>$136</td>
</tr>
</tbody>
</table>

According to data compiled by Bloomberg, “prices have dropped below the level needed by at least 9 OPEC member states to balance their budgets.”


*Survival of fittest as oil tumbles below $65*, Bloomberg News, December 1, 2014
Uncertainty:
An Assessment of the Geopolitical Backdrop
The Problem?

Iran  China  Russia

Are playing for the long-term
The Answer?

• The short cycle U.S. shale business model is something that OPEC countries don’t understand and apparently can’t compete with.

• They would have to understand Capitalism and fee ownership of minerals to get it.

• Try explaining George Mitchell and his persistence to someone in the Middle East.
U.S. Dry Shale Gas Production

Source: EIA Natural Gas Weekly Update, 03 May 2018
©LNG Allies, 2018
U.S. Natural Gas Production, Consumption, Imports

Source: EIA Annual Energy Outlook - 2018
©LNG Allies, 2018

US supply growing again; largest year-over-year gain in history

Source: S&P Global Platts Analytics

Source: Rick Allen, S&P Global Platts, The Energy Summit – COGA 2018 presentation, August 22, 2018
Source: EIA Annual Energy Outlook 2018 (Reference Case) ©LNG Allies, 2018

Difference between production and consumption = volume available for export by LNG and pipeline.
U.S. Natural Gas Production and Consumption

trillion cubic feet per year

Dry Gas Production
Domestic Consumption

Difference between production and consumption = volume available for export by LNG and pipeline.

Source: EIA Annual Energy Outlook 2018 (High Oil & Gas Case) ©LNG Allies, 2018

Major delays on Mexico’s interior gas pipelines

- 4.7 Bcf/d delayed downstream of West Texas
- 4.9 Bcf/d delayed downstream of South Texas
- Average delay over 400 days
- Most new capacity delayed past 2018
- US pipeline exports will remain capacity constrained until 2019

Source: SENER, S&P Global Platts Analytics
Downstream constraints alleviated in 2019

MEXICO IMPORT CAPACITY CONSTRAINTS (BCF/D)

Imports peak at ~4.9 Bcf/d in Oct-18
Imports peak at ~6.2 Bcf/d in Jul-19

Source: S&P Global Platts Analytics

Source: Rick Allen, S&P Global Platts, The Energy Summit – COGA 2018 presentation, August 22, 2018
## Permitting Status of U.S. LNG Export Projects

<table>
<thead>
<tr>
<th>Project Stage</th>
<th>Projects</th>
<th>MTPA</th>
<th>Bcm/yr</th>
<th>Bcf/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating / Under Construction</td>
<td>6</td>
<td>70.9</td>
<td>97.7</td>
<td>10.0</td>
</tr>
<tr>
<td>Fully Permitted (Major Projects)</td>
<td>4</td>
<td>68.9</td>
<td>95.0</td>
<td>9.7</td>
</tr>
<tr>
<td>Fully Permitted (Small Projects)</td>
<td>N/A</td>
<td>9.0</td>
<td>12.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Formal FERC Review</td>
<td>11</td>
<td>146.9</td>
<td>202.6</td>
<td>20.9</td>
</tr>
<tr>
<td>FERC Pre-Filing</td>
<td>2</td>
<td>24.0</td>
<td>33.1</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
<td><strong>310.7</strong></td>
<td><strong>428.5</strong></td>
<td><strong>44.0</strong></td>
</tr>
</tbody>
</table>

Notes: (1) Projects = individual projects. (2) Additional trains for existing projects not included in the project count, but in the MTPA, Bcm/year, and Bcf/day totals (Sabine Pass #6, Corpus Christi #3, Cameron #4 #5, Freeport #4).

Source: Federal Energy Regulatory Commission & LNG Allies (17 April 2018) ©LNG Allies, 2018
Major U.S. LNG Export Projects - Existing & Proposed

Includes Train 4 - Pending at FERC (5.1 MTPA)
Includes Trains 4-5 FERC Pre-Filling (10.0 MTPA)

Sources: LNG Allies, EIA, DOE (Dec. 2017)

©LNG Allies, 2017

U.S. LNG Liquefaction Capacity Growth

Source: LNG Allies (Based on Trade Press & Company Data) ©LNG Allies, 2018
High Utilization of US LNG Expected to Persist

Source: S&P Global Platts Analytics

Source: Rick Allen, S&P Global Platts, The Energy Summit – COGA 2018 presentation, August 22, 2018
Latin America and Asia main markets US LNG

1,240 BCF US LNG exports shipped to 27 countries

*Numbers may not add up to 100% due to rounding

Source: S&P Global Platts Analytics

Source: Rick Allen, S&P Global Platts, The Energy Summit – COGA 2018 presentation, August 22, 2018
Asia Clearly Driving LNG Demand

LNG Demand in Asia expected to account for roughly 50% of the total LNG demand growth 2023 v 2018

Source: S&P Global Platts Analytics

Source: Rick Allen, S&P Global Platts, The Energy Summit – COGA 2018 presentation, August 22, 2018
China almost 30% of growth in global LNG demand (2018 to 2023)

Source: S&P Global Platts Analytics

Source: Rick Allen, S&P Global Platts, The Energy Summit – COGA 2018 presentation, August 22, 2018
North America LNG Outlook

- North America LNG supply competitive with rest of world for delivery to Asia
- Deliveries to Europe are competitive but margins are thinner
- Cost competitiveness is not the only factor in determining market share

Source: Greg Ruben, Kinder Morgan, Colorado Oil and Gas Association Trade presentation, August 21, 2018
Projected Net North America LNG Exports

Source: Greg Ruben, KinderMorgan, Colorado Oil and Gas Association Trade presentation, August 21, 2018
World LNG Estimated Landed Prices: May-18

Note: Includes information and Data supplied by IHS Global Inc. and its affiliates ("IHS"). Copyright (publication year) all rights reserved. Prices are the monthly average of the weekly landed prices for the listed month. Landed prices are based on a netback calculation.

Updated: Jun-18
Key Questions

• It is all about efficiency. Is the independent publically traded North American Energy company more efficient than a foreign state-run energy group?

• If you are a foreign buyer of a 20-year supply of natural gas, how meaningful is the security that emanates from a country that supports the rule of law?

• Can any other country mimic the efficiency of a system that allows for the private ownership of mineral interests?

• Can the renewable energy industry significantly undermine the market share of the oil and gas industry?

Source: Rick Allen, S&P Global Platts, The Energy Summit – COGA 2018 presentation, August 22, 2018
Key Takeaways

• Forecasted North American production growth is highly dependent on global export markets; more exports to Mexico and LNG (10.3 Bcf/d) than organic demand growth in Canada and US (5.7 Bcf/d)

• Global demand for LNG continues growing; expect a “second wave” of U.S. LNG liquefaction capacity

• Gas infrastructure development is required to connect supply centers with emerging demand

• U.S. natural gas producers are dependent upon export growth

Source: Rick Allen, S&P Global Platts, The Energy Summit – COGA 2018 presentation, August 22, 2018
Key Takeaways About You

• The Shale workforce of the future will require the following abilities related to statistics, mathematics, computer science, data processing, data science and artificial intelligence:
  • Industry knowledge
  • Analyze large quantities of data to draw conclusions
  • Produce usable data for analyses from unstructured “messy” real-world sources
  • The theoretical and applied study of algorithms, equations, functions, etc.
  • Program computers to perform defined tasks (ie – analyze, optimize)
  • Simulation of human intelligence by machines (ie – machine learning, natural language processing, machine vision, robotic processing automation

Source: Shale’s radically changing workforce, Paul Goydan and Jamie Webster, Boston Consulting Group
Contact Information

John Harpole
President
Mercator Energy
26 W. Dry Creek Circle, Suite 410
Littleton, CO 80120
harp@mercatorenergy.com
(303) 825-1100 (work)
(303) 478-3233 (cell)
Who really knows where the price will go?

87% of NYMEX HH contract open interest positions are in the nearby 3 months.

There is no long term price liquidity in the NYMEX natural gas contract.

The bid-ask spread on any contract beyond a 2-year term reflects that lack of liquidity.