The U.S. Shale Revolution – What Happened and What’s Next?

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First the bad news (for petroleum engineers)

- Historically, oil prices are usually low
The average oil price in 2010 $ for the past 65 years is about $30/bbl!
When oil or gas prices fall, drilling activity decreases, often drastically.
Weekly natural gas rig count and average spot Henry Hub

active rigs

$ per MMBtu

Source: Baker Hughes
Unprecedented increases in U.S. oil production from unconventional reservoirs have contributed to the current oversupply of oil.
North American shale plays
(as of May 2011)

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011
Texas Crude Oil Production, January 1981 to August 2014

Barrels per day

Oil Output Doubled from October 2011 to August 2014

Source: EIA

Carpe Diem Blog
Outline

• The Enabling Technologies for U.S. Production Growth
  ▪ Horizontal Drilling
  ▪ Hydraulic Fracturing
Horizontal Drilling has been an enabling technology.

Much of the Horizontal Drilling technology was developed during the Austin Chalk development in Texas in the 1990’s
Hydraulic Fracturing

- Hydraulic fracturing is the process of using hydraulic pressure to create an artificial fracture in a reservoir.
- The fracture grows in length, height and width by pumping a mixture of hydraulic fluid and propping agents at high pressure into the well bore.
- The purpose of a fracture is to alter the flow pattern in the reservoir to increase the oil and gas flow rates.
Hydraulic Fracturing Operations

- **Proppant**
- **Pumper**
- **Wellhead**
- **Blender**
- **Frac Fluid**
- **Injection**
- **Fracture Created With Hydraulic Pressure (Water Based Frac Fluid)**
- **Oil or Gas Zone**
Hydraulic Fracturing Operations

- **Blender**
- **Proppant**
- **Pumper**
- **Wellhead**
- **Injection**
- **Clean Fluid (Pumped First)**
- **Proppant Mixed With Frac Fluid**

Blender 
Proppant 
Pumper 
Wellhead 
Injection 
Clean Fluid (Pumped First) 
Proppant Mixed With Frac Fluid
Hydraulic Fracturing Operations

Fluid Blender Pumper Wellhead Injection

Proppant Pumped Into Fracture
Hydraulic Fracturing Operations

Flow “Broken” Frac Water Out of Well into Tanks At Surface
Hydraulic Fracturing Operations

Gas Starts Flowing From Fracture After Water Clean-up

Flow to Sales

Production
Complex Fractures in Shale

• Actual confirmation of hydraulic connection of complex fracturing was provided by Fisher (2004), when the extremely complex fractures predicted in the Barnett fraced into and temporarily killed five of the surrounding six wells

• Clouds of microseismic events are a good sign of complex fracturing
Our Understanding is Rapidly Improving – Example: Fracture Diagnostics

- Microseismic Imaging
- Distributed Temperature Sensing (DTS)
- Distributed Acoustic Sensing (DAS)
Microseismic Activity from Stimulation Treatments (Waters et al. SPE 119635)
Locating Transverse Hydraulic Fractures Created from Horizontal Wells

Barnett shale horizontal well

- Fracture detection is based on the fact that the fracture fluid is typically much cooler than the formation temperature.
- The fracture location can be identified as a cool region on the temperature log, particularly after a period of shut-in.
- A series of DTS-measured temperature profiles acquired during the multi-stage hydraulic fracturing.
Locating Transverse Hydraulic Fractures Created from Horizontal Wells

Temperature profile at the start of Stage 3 injection
Distributed Acoustic Sensing Technology for Fracture Diagnosis

- Technology is available for fracture diagnosis (propagation and rate)
- Quantitative interpretation remains a challenge
Comprehensive and Integrated Research to Develop Predictive Models for Shale Oil and Gas Reservoirs in Texas

The Crisman Institute for Petroleum Research
and
The Berg-Hughes Center for Petroleum and Sedimentary Systems
Global Oil Production

● Oil production has increased in many places around the world, not just North America.

● December 16th, 2014: Production operated by Petrobras (Brazil) in the pre-salt breaks new record and passes the 700 thousand barrels of oil per day mark.

● Production from Africa has increased by several million b/d in the past few years.
Short-Term Outlook

- Barring a major geopolitical event that disrupts supply, oil and gas prices will remain low until the current oversupply is absorbed

- Oil and gas activity in the U.S. will remain greatly reduced
So how about some good news?

- Without continued high level of drilling, U.S. oil production will begin to decline
Wells Permitted and Completed in the Eagle Ford Shale Play
March 02, 2015

Well Legend

- 6,364 Permits
- 7,394 On Schedule - Oil
- 4,837 On Schedule - Gas

Note: There are 6,364 permitted locations representing pending oil or gas wells, where either the operator has not yet filed completion paperwork with the Commission, or the completed well has not yet been set up with a Commission identification number.
Average oil production per well during the first 48 months of operation
barrels per day

first full month of production

2014
2013
2012
2011
2010
2009

month of operation
Some even better news

- All long term forecasts predict significant growth in oil and gas production

- Global energy demand will continue to rise for many years
ExxonMobil
The Outlook for Energy: A View to 2040
Gas & Oil Still ‘Kings’ In 2040!

Solar + Wind + Biofuel: ~5% Of The Global Energy Mix In 2040

Quadrillion BTUs

- Nuclear
- Hydro
- Gas
- Oil
- Coal
- Biomass
The world needs 6 million boepd of new oil production every year

- Global natural decline is: 5 mill boepd/yr
- Global demand grows by: 1 mill boepd/yr

Source: Interview with DN February 21, 2015

SHELL CEO
BEN van BEURDEN
Fast forward 5 years with zero increase in demand and the gap is 20 million boepd.
World Economic Forum, Davos, Switzerland, January 2016:

- About 2000 CEO’s
- Heads of State
- Government ministers
Daniel Yergin:

- Hedge funds and private equity groups armed with $60bn of ready cash are ready to snap up the assets of bankrupt US shale drillers – shale development will rebound rapidly.

- “It takes $10bn and five to ten years to launch a deep-water project. It takes $10m and just 20 days to drill for shale,” he said, speaking at the World Economic Forum in Davos.
World Economic Forum, Davos, Switzerland:

- Fatih Birol, head of the International Energy Agency, said the suspension of new projects is setting the stage for a powerful spike in prices.
- Investment fell 20% last year worldwide, and is expected to fall a further 16% this year. “This is unprecedented: we have never seen two years in a row of falling investment. Don’t be misled, anybody who thinks low oil prices are the ‘new normal’ is going to be surprised,” he said.
World Economic Forum, Davos, Switzerland:

• Ibe Kachikwu, Nigerian oil minister and the outgoing chief of OPEC, said the ground is being set for wild volatility.

• “The bottom line is that production no longer makes any sense for many, and at this point we’re going to see a lot of barrels leave the market. Ultimately, prices will shoot back up in a topsy-turvy movement,” he said.
In summary:

- Long term energy demand will result in expanding oil and gas activity

- Oil and gas will remain the primary source of energy for many years to come

- Oil prices will rise sharply when demand exceeds supply – as soon as later 2016
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