Unconventional Reservoir Future
Science, Technology and Economics

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Outline

- Unconventional Reservoirs
- U. S. Shale Gas and Shale Oil
- Science, Technology & Economics
Global Natural Gas

Resources v. Cost

Global Consumption
115 Tcfy

Global Oil

Resources v. Cost

U.S. Natural Gas

Production and Reserves

Data: BP World Energy 2012
U.S. Natural Gas

Production (TcF)

An Anticipated Evolution

From a 2004 Tinker Talk to the IPAA
US Natural Gas 2004 forecast

- Total Natural Gas
- Conventional Gas
- Unconventional Gas

Annual Natural Gas Production (Bcf)

- Shale gas
- Coalbed methane
- Tight gas
- Non-associated offshore
- Alaska
- Associated with oil
- Non-associated onshore


http://www.eia.gov/energy_in_brief/about_shale_gas.cfm
Shale Gas Forecast vs. Actual

Model: Rice University, Medlock, 2012

Actual
Annual US Oil Production

2010 U.S. SHALE LIQUIDS PROJECTION

United States Consumption

~ 7 Bby

~ 1.4 Bby from shale by 2022

After Morse et. al., 2012, Energy 2020: North America, the new Middle East: Citi GPS: Global Perspectives & Solutions, figure 14, p. 17.

IRR Source: Rystad Energy
Annual US Oil Production

U.S. Production
~ 3.1 Bby Today!

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Unconventional Resource Plays

Modified from: EIA and National Geographic
Unconventional Resource Plays

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Unconventional Resource Plays

- Marcellus
- Fayetteville
- Haynesville
- Barnett
- Bakken
- Eagle Ford
- Permian Basin

Middle Devonian

From Blakey; http://cpgeosystems.com/paleomaps.html
Bureau of Economic Geology

U.S. Shale Gas Integrated Study

- What is the *total* resource base in place?
- What portion is *technically* recoverable?
- What portion is *economically* recoverable?
- What is the long-term *production outlook*?
Barnett Productivity Tiers

Well Profiles Vary by Tier

Barnett Historical

- Variable leases
- Multiple operators
- Wide range of completion types

BEG Shale Reserves and Production Project
Production Outlook for the Barnett Shale through 2030

Base Case Production by Year

Gas Price $4.00/mcf

45 Tcf

Source: Bureau of Economic Geology/Univ. of Texas at Austin
**Barnett**

Production Forecast

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Tcf per Year

(Base Case Sensitivity to Price)

- **Tcf @ $10 HH**
- **Tcf @ $6 HH**
- **Tcf @ $4 HH**
- **Henry Hub $2010**

**45 Tcf**

**BEG Shale Reserves and Production Project**
Barnett Monte Carlo Production Distribution

OGIP 444 TcF

35 Tcf

56 Tcf

Cumulative Production (TcF)

Relative Frequency

Browning, J. et al. 2013. SPE Econ & Mgmt
Fayetteville
Productivity Tiers

30-Year Natural Gas Productivity Extrapolated
Fayetteville Shale Play, Arkansas
Tier 1 - 6

Each Arkansas PLSS Section is colored based on the estimated productivity of the average 4,400 ft. horizontal well in that section. 30-year production projection (Bcf).
Fayetteville Production Forecast

Cumulative % Inventory Drilled

Fayetteville Drilling by Tier

- Tier 1
- Tier 2
- Tier 3
- Tier 4
- Tier 5
- Tier 6

BEG Shale Reserves and Production Project
Fayetteville Production Forecast

BEG Shale Reserves and Production Project
Fayetteville

Monte Carlo Production Distribution

OGIP 80 TcF

13 TcF

23 TcF

BEG Shale Reserves and Production Project
Haynesville
Productivity Tiers

25 - Year Natural Gas Productivity
*Extrapolated*
Haynesville Shale Play, TX and LA

Each 1 mi² block is colored based on the estimated productivity of the average 4,800 ft. horizontal well in that area (Bcf).

Sources
Base map features acquired from TNRIS and SONRIS, USGS
Quadrangles Indices (1/64) were adapted from the USDA Geospatial Data Gateway, available online: http://datagateway.nrcs.usda.gov/GDDOrder.aspx
Well data provided by IHS and Drillinginfo; well logs provided by MJ Systems.
Map compiled in ESRI ArcMap 10.2
GCS WGS 1984
Datum: D WGS 1984
Prime Meridian: Greenwich
Angular Unit: Degrees
Haynesville Production Forecast

Cumulative % Inventory Drilled

Haynesville Drilling by Tier

Tier 1
Tier 2
Tier 3
Tier 4
Tier 5
Tier 6

2008 2009 2010 2011 2012

BEG Shale Reserves and Production Project
Haynesville Production Forecast

BEG Shale Reserves and Production Project

37 Tcf
Haynesville
Monte Carlo Production Distribution

OGIP 489 TcF

24 TcF

62 TcF

BEG Shale Reserves and Production Project
BEG Shale Reserves and Production Project
Economics by Tier (Bcf)

Breakeven Economics
10% IRR

$6 Case

Tier 1  Tier 2  Tier 3  Tier 4  Tier 5  Tier 6  Tier 7  Tier 8  Tier 9  Tier 10

Barnett Low Btu
Barnett High Btu
Fayetteville Shallow
Fayetteville Medium
Fayetteville Deep
Haynesville

BEG Shale Reserves and Production Project
Marcellus OGIP

1712 Tcf OGIP free

BEG Shale Reserves and Production Project
**Base Case ($4) Stacked Production**

- **Marcellus**
- **Haynesville**
- **Fayetteville**
- **Barnett**

**U.S. Consumption**

~ 25 TcF/Year

**BEG Shale Reserves and Production Project**

- 45 TcF
- 37 TcF
- 17 TcF
- 45 TcF

**Henry Hub Price ($2012/MMBtu)**

- 1995
- 2000
- 2005
- 2010
- 2015
- 2020
- 2025
- 2030
EIA Price Case Stacked Production

U.S. Consumption ~ 25 TcF/Year

BEG Shale Reserves and Production Project
$6 Case Stacked Production

U.S. Consumption ~ 25 TcF/Year

Marcellus
Haynesville
Fayetteville
Barnett
HH $2012

Henry Hub Price ($2012/MMBtu)

BEG Shale Reserves and Production Project
Forecast vs. Actual

Model: Rice University, Medlock, 2012

EIA price deck

BEG

EIA
Global Natural Gas

Resources v. Cost

BEG Original Gas in Place (Tcf)
- Barnett: 444 Tcf
- Fayetteville: 80 Tcf
- Haynesville: 489 Tcf
- Marcellus: 1712 Tcf (2050)
- Total: 2725 Tcf

BEG ($4) Production – 2050
- Barnett: 45 Tcf
- Fayetteville: 17 Tcf
- Haynesville: 37 Tcf

Field Wide Recovery %
- Barnett: 10%
- Fayetteville: 21%
- Haynesville: 8%

Outline

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The 5E Waltz

Environment

Education

Energy

Economy
The Radical Middle

- Academia/NGO
- Government
- Industry

Tinker, 2014
Some Key Questions

- Can we **re-complete** existing wells economically?
- Will technology and economics allow for development of the large OGIP and OOIP in **middle tiers**?
- Can we improve **facilities** and manage flaring, choking of wells and other operational limitations?

- Can we improve fracture characterization and increase the number of **contributing stages**?
- Do we understand **rock mechanics** and what creates surface area?
- Can we forecast and **manage decline** of production and improve our estimates of EUR?
- Can we drill **fewer wells** from fewer pads?
- Can we use **less water**?

- What controls induced fracture morphology and can we improve our **imaging of fracture** networks?
- Can we improve **characterization** of hydraulic fractures by deploying smart nanosensors?
- Can we improve our understanding of **adsorbed gas**? **Porosity**? **Permeability**?
TPER = Total Primary Energy Requirement. Energy needed to facilitate Total Final Consumption (TFC does not include conversion and transmission losses).

After: Rice World Gas Trade Model
Medlock, 2012
Energy and the Economy

TPER = Total Primary Energy Requirement. Energy needed to facilitate Total Final Consumption (TFC does not include conversion and transmission losses).

~3 billion people

After: Rice World Gas Trade Model
Medlock, 2012
Energy and the Economy

A Global Challenge

TPER = Total Primary Energy Requirement. Energy needed to facilitate Total Final Consumption (TFC does not include conversion and transmission losses).

Developed Nations
- Balance of Trade
  - Exports
  - Imports
- Regulation and Planning
  - Infrastructure
  - Resources
  - Permitting
- Emissions, Climate, Environment
- Energy Security

Developing Nations
- Food
- Housing
- Clothing
- Education
- Healthcare
- Electricity

After: Rice World Gas Trade Model
Medlock, 2012
Oil “Frontiers”
Unconventional Technology for Conventional Reservoirs

Tinker’s Top Ten

1. Governments, industry and academe must work together; we all play a role in objective, balanced energy education.
2. The scale of energy demand is difficult to comprehend; energy transitions take many, many decades.
3. Energy security — affordable, available, reliable, sustainable — drives the energy mix and should be the goal of energy policy.
4. Energy efficiency is underappreciated; individuals matter!
5. Diverse energy portfolios are inevitable and healthy.
6. Renewables are growing but will remain regional supplements until major advances are made in energy storage.
7. Shale will play a global role in the energy future; “above ground” challenges are as important as “below ground.”
8. Natural gas and nuclear are the new foundational energies.
9. Oil and coal are abundant at the right price, and difficult to replace as transportation and electricity fuels.
10. Energy, the economy and the environment are linked.