SPE 135555: Shale Gas Production Decline Trend Comparison over Time and Basins

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Overview

- Objectives
- Motivation
- Formations Analyzed
- Methodology
- Horizontal Shale Basin Results
- Vertical to Horizontal Well Comparison
- Sandstone and Shale Horizontal Well Comparison
- Economic Analysis
- Conclusions

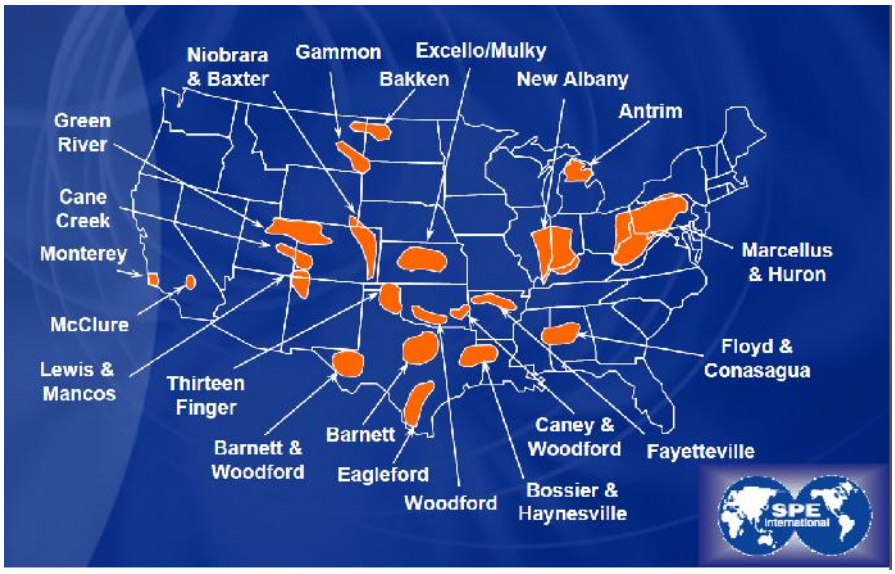
Objectives

- Examine production trends in horizontal shale gas wells over time in a given basin
- Compare the production profiles between shale basins
- Compare historical production of vertical and horizontal Barnett Shale wells
- Compare the production profiles of horizontal tight gas sandstone and shale formations
- Perform a basic economic analysis of the average shale basin horizontal well

Motivation

- Disagreement within the industry in shale plays over
  - Long term viability
    - Decline trends
    - Time to abandonment rate
    - EUR
    - Resultant economics

Formations Selected for Analysis



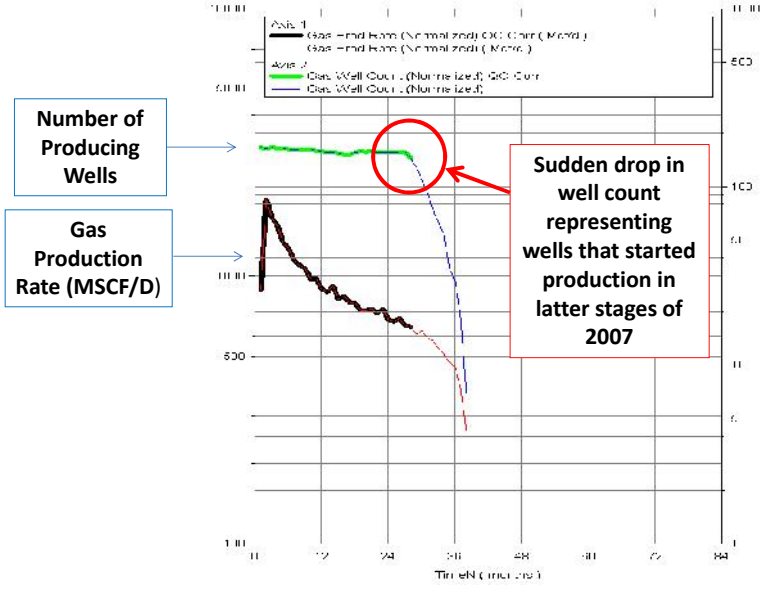
Methodology for Production Analysis

- Core area was chosen in each shale basin based upon
  - Limit the number of wells for analysis
    - Perform proper QA/QC on a well by well basis
  - Wells not on the periphery of the play
  - Horizontal wells drilled since the inception of the basin
  - Better producing area in the play
- Eagle Ford gas area was analyzed and due to low well count, the entire play was analyzed
- Hundreds of horizontal wells chosen in each play
- Each play was analyzed individually

Methodology for Production Analysis

- Monthly production broken down into daily rates
- All wells not exhibiting a normal decline trend were excluded
- Wells were grouped by date of first production
- Data sets with less than eight wells were ignored
- Wells falling an order of magnitude or more outside of the trend were scrutinized further
- Data normalization
  – Shift all well production data to a specific ‘time zero’
- Once the well count fell drastically, the analysis was stopped

Data Quality Control



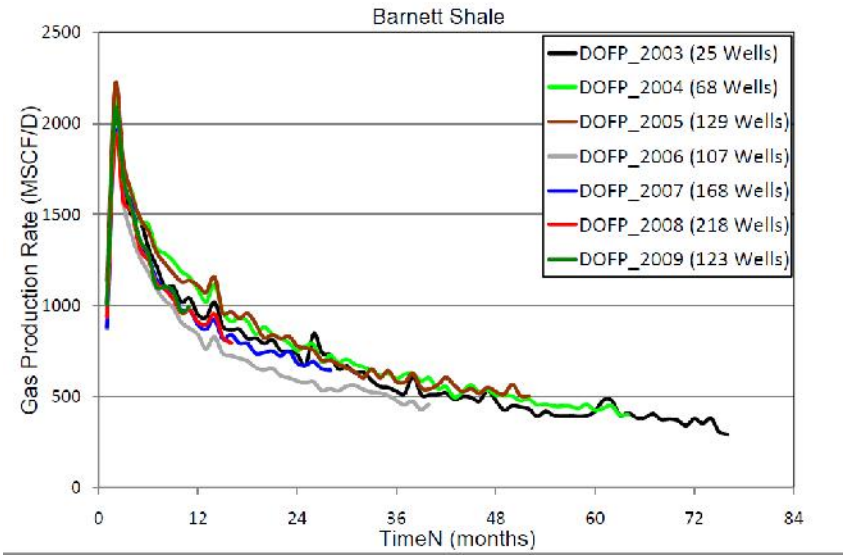
Number of Wells Analyzed

Case	Total Wells #
Barnett	731
Fayetteville	467
Woodford	305
Haynesville	275
Eagle Ford	59

Forecast Method

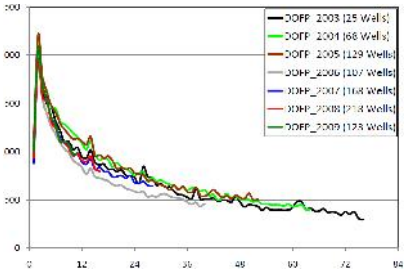
- Decline curve analysis (DCA)
  - Determine Arps' b exponent from regression of historical production data for each group
- Forecast analysis
  - Formulate a production type curve for each shale gas basin from DCA

Barnett Shale
Maximum Time Decline Trend



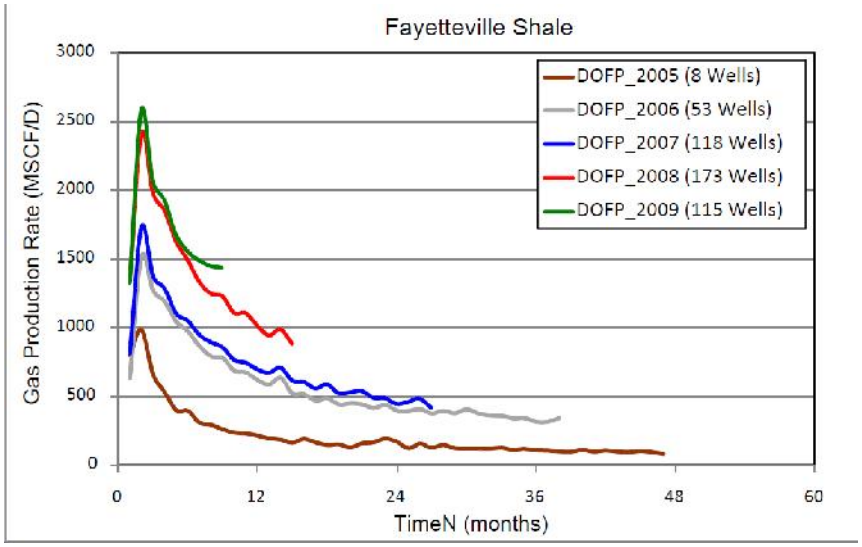
Barnett Shale Summary

- IP's and decline trends are similar over time
  - Open natural fractures
  - Low stress anisotropy
  - Pipeline capacity maxed out

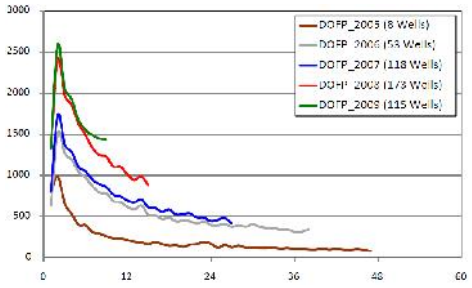


- Wells are not interfering with one another
  - Some wells have frac'd into one another
- Increasing from two to six frac stages over time
- Proppant per stage decreasing as number of stages increased
- One study found that proppant amount correlated well to production results

Fayetteville Shale
Maximum Time Decline Trend

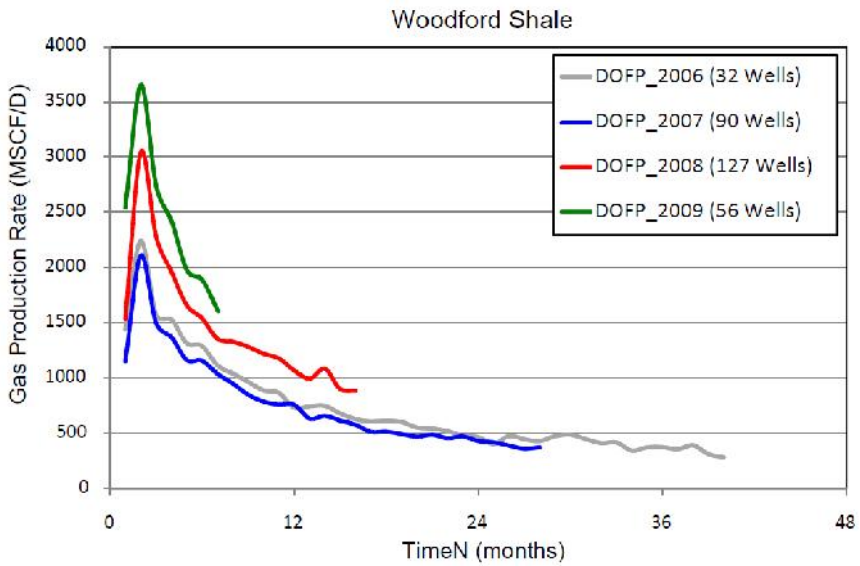


Fayetteville Shale Summary



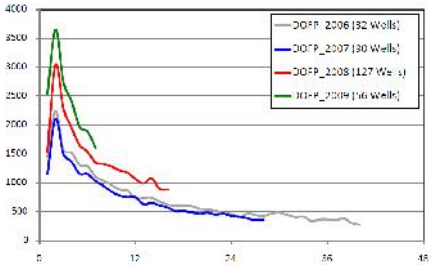
- IP's and production increase over time
  - Lateral length increased from 1,800 to 4,300 ft
  - Frac stages per lateral went from 3-4 to 6-8
  - Fluid volume per lateral has doubled
  - Proppant amount per lateral has tripled
- Production decline trends are fairly parallel over time
- Increase in production appears to be sustained

Woodford Shale
Maximum Time Decline Trend

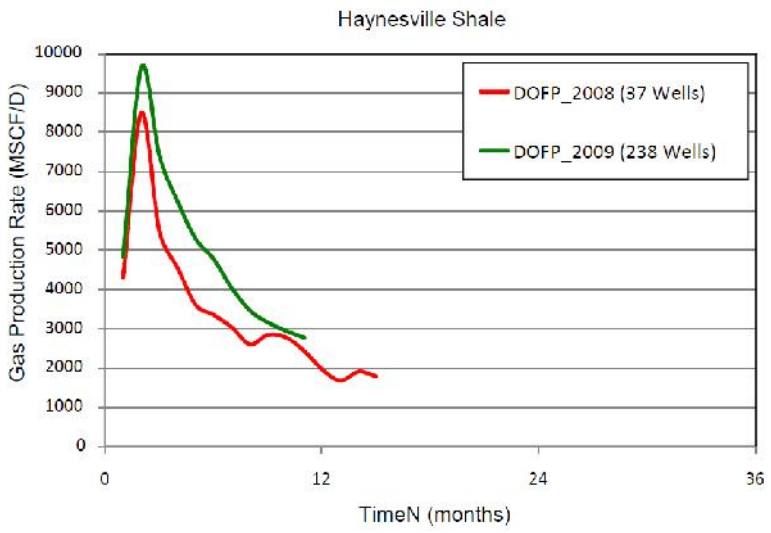


Woodford Shale Summary

- IP's and production increase over time
  - Lateral length increased 1,800 to 4,800 ft
  - Frac stages per lateral went from 3 to 10
  - Fluid volume has increased, but not proportionately
  - Proppant amount per lateral has remained constant
- Production decline trends are somewhat parallel over time
- Increase in production may be sustained, more production is needed
- Decline profile similar to the Fayetteville

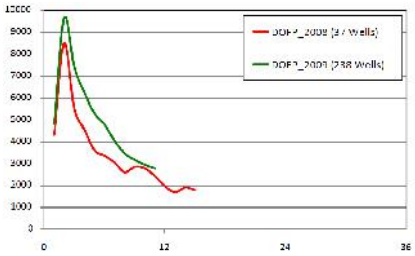


Haynesville Shale
Maximum Time Decline Trend



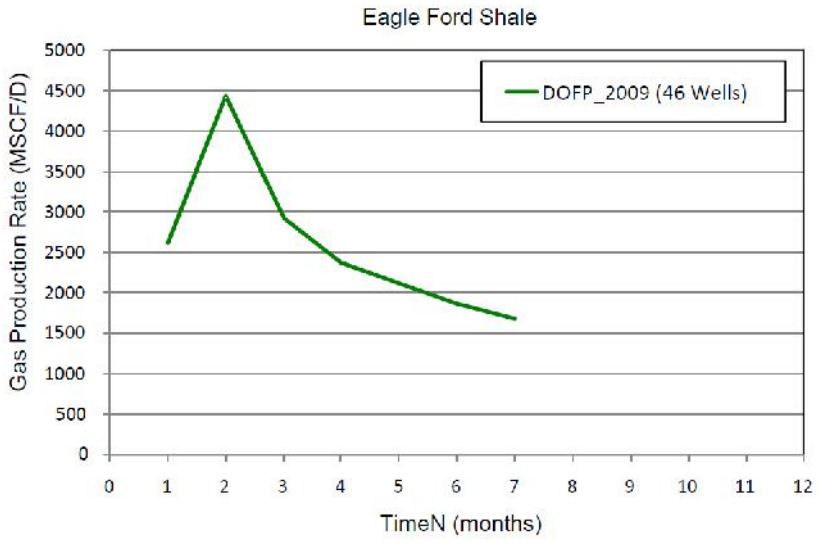
Haynesville Shale Summary

- IP's have increased by 18% year on year
  - Completion trends have rapidly evolved
  - Lateral length increased 2,200 to 4,800 ft



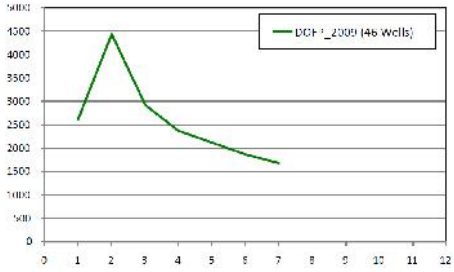
  - Frac stages per lateral increased from 6 to 14
  - Stimulation volumes have increased proportionately to the number of stages
  - Fluid volume per stage ~12,000 bbl
  - Proppant amount per stage ~300,000 lbs
- Production decline trends are fairly parallel over a short timeframe

Eagle Ford Shale Decline Trend



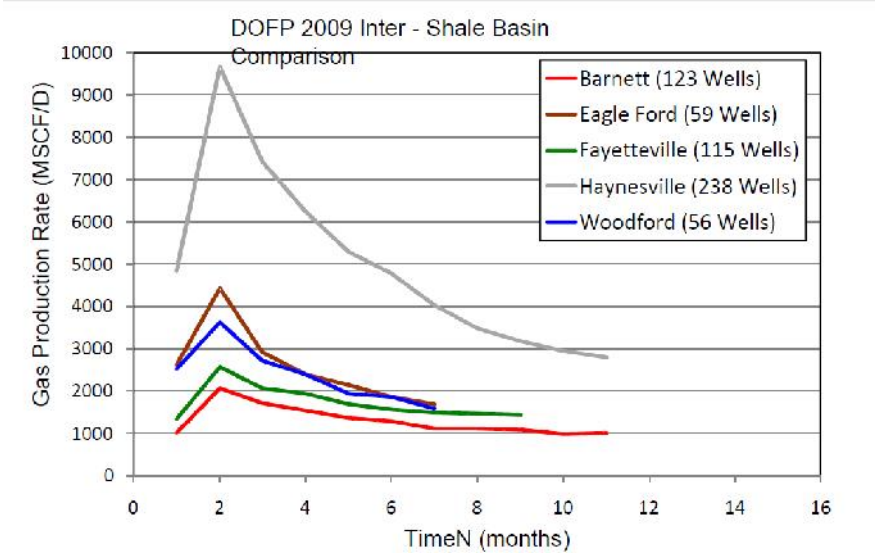
Eagle Ford Shale Summary

- IP is second highest over shale plays analyzed
  - Lateral length is ~5,000 ft
  - Frac stages per lateral are 12 to 14
  - Frac designs are comparable to the Haynesville Shale

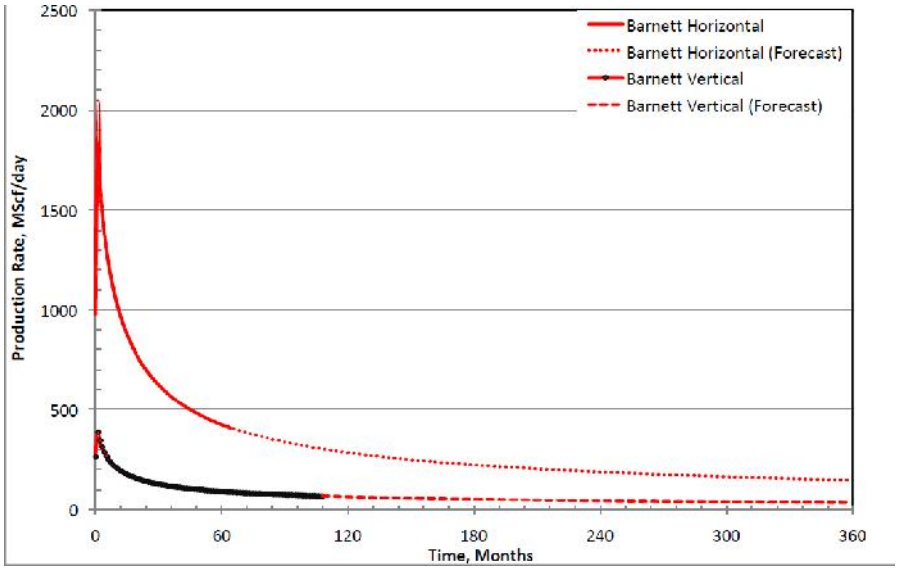


- More time needed to perform additional analysis

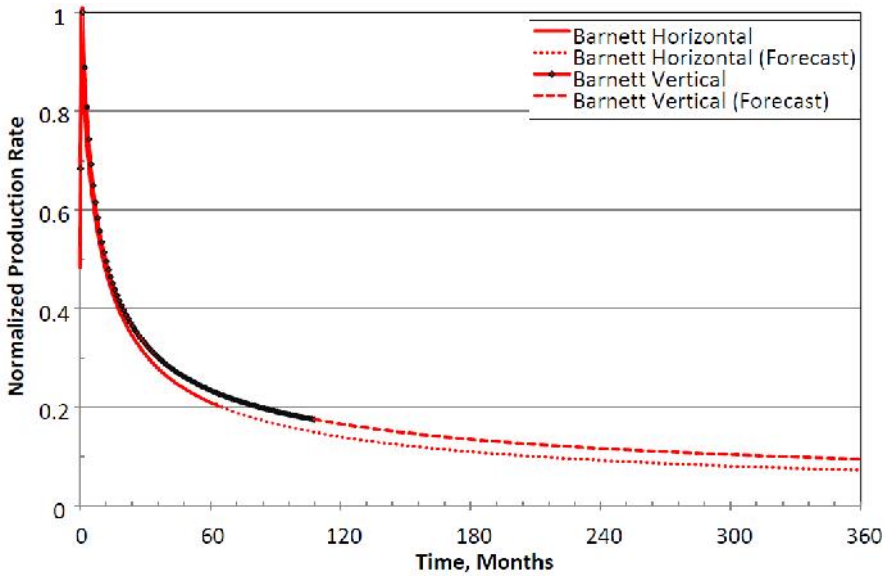
2009 DOFP Inter Shale Basin Comparison



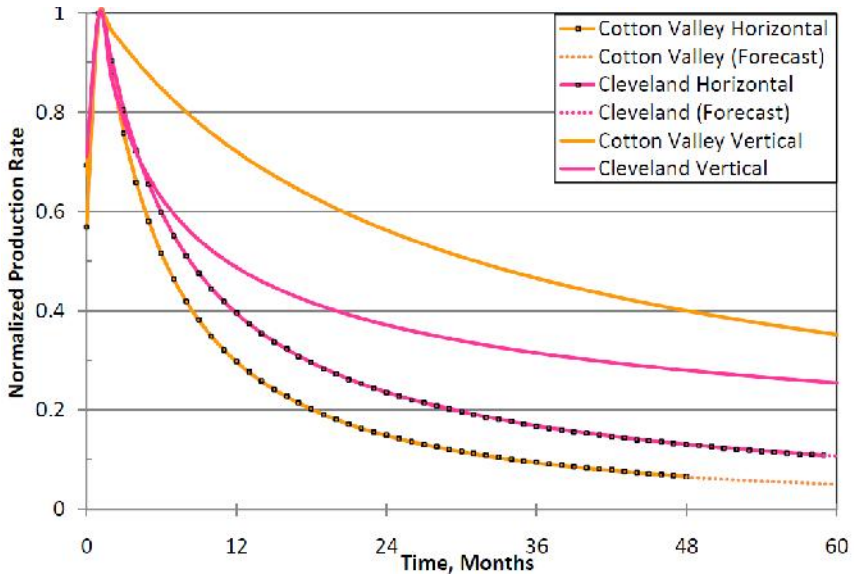
Absolute Gas Production Rate for Barnett Horizontal and Vertical Wells



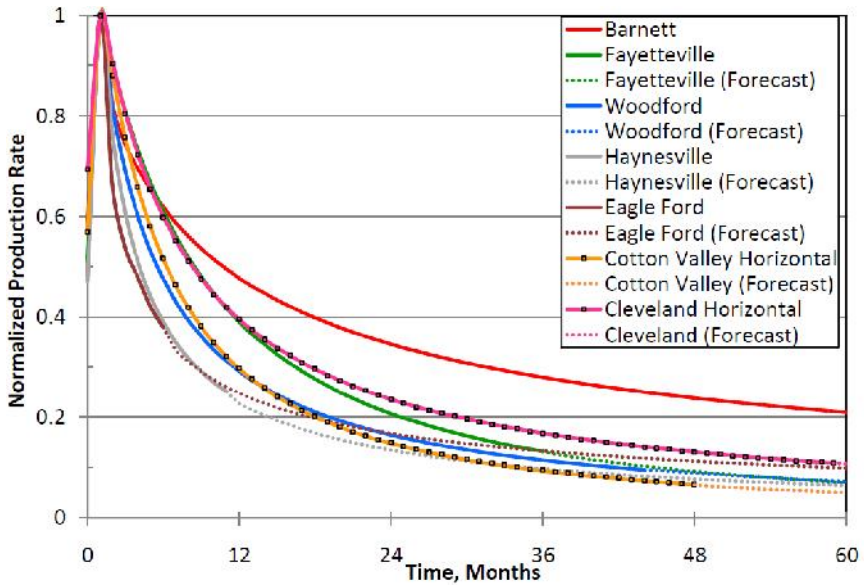
IP-Normalized Gas Production Rate for Barnett Shale Horizontal and Vertical Wells



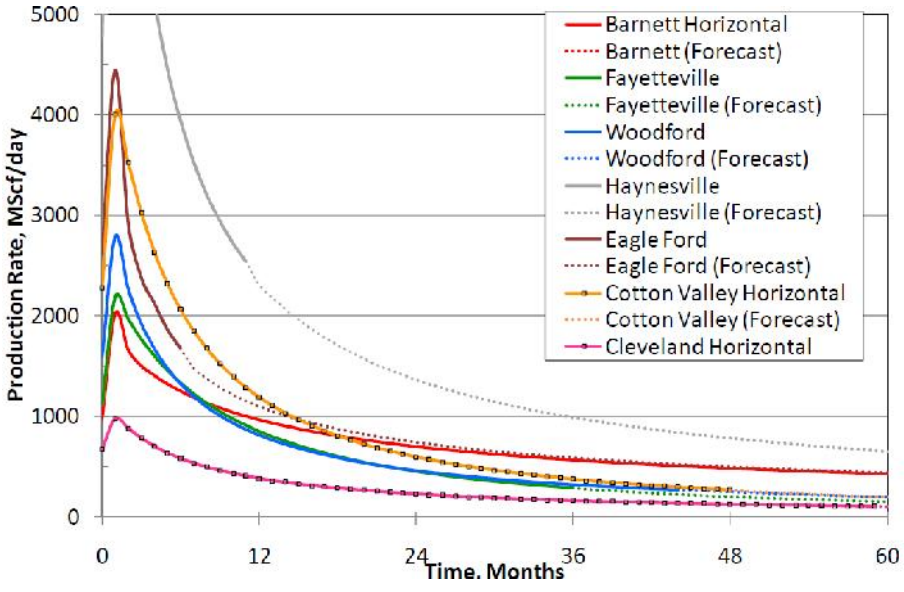
Overlay of IP-Normalized Production Type Curves for Horizontal and Vertical Sandstones



Overlay of IP-Normalized Production Type Curves for Horizontal Sandstone and Shale Plays



Overlay of Absolute Production Type Curves for Horizontal Sandstone and Shale Plays



Comparison of DCA for Various Plays

Case	Reservoir Type	Well Type	b	Current Cumulative Gas Production MMScf
Barnett	Shale Gas	Horizontal	1.5933	1,415
Fayetteville			0.6377	883
Woodford			0.8436	996
Haynesville			1.1852	1,740
Eagle Ford			1.6940	548
Cotton Valley	Tight Gas Sandstone		0.7259	1,341
Cleveland			1.0000	478
Cotton Valley (1980)		Vertical	1.2778	2,703
Cleveland (1980s)			2.3483	476
Cotton Valley (>2005)			1.0000	469
Barnett (1980s)	Shale Gas		1.9366	389

Economic Inputs

Play	Well Cost $MM	Royalty %	Operating Cost $/MScf
Barnett	3	22	0.7
Fayetteville	2.8	17	1.1
Woodford	6.7	19	1.2
Haynesville	8	25	2.5
Eagle Ford	5.8	25	1.5

Economic and Production Results

	Before Tax @ $4/MScf				
Case	DPI@0%	DPI@10%	DPI@15%	ROR,%	EUR,Bcf
Barnett_DOFP_2008	2.11	1.11	0.92	12.6	2.895
Barnett_DOFP_2009	2.09	1.1	0.92	12.3	2.867
Fayetteville_DOFP_2008	1.95	1.15	0.99	14.7	2.463
Fayetteville_DOFP_2009	2.69	1.43	1.19	22.1	3.401
Woodford_DOFP_2008	0.71	0.42	0.37	0	2.544
Woodford_DOFP_2009	0.94	0.53	0.45	0	3.389
Haynesville_DOFP_2008	0.29	0.19	0.16	0	4.579
Haynesville_DOFP_2009	0.38	0.24	0.21	0	6.092
Eagle Ford_DOFP_2009	0.83	0.45	0.38	0	3.793
Cotton Valley_Horizontal	0.92	0.69	0.64	0	2.036

Economic Break Even Price

Case	EUR, Bcf	Gas Price (DPI @ 10% = 1) (USD)
Barnett_DOFP_2008	2.895	$3.70
Barnett_DOFP_2009	2.867	$3.74
Fayetteville_DOFP_2008	2.463	$3.65
Fayetteville_DOFP_2009	3.401	$3.20
Woodford_DOFP_2008	2.544	$7.35
Woodford_DOFP_2009	3.389	$6.22
Haynesville_DOFP_2008	4.579	$6.95
Haynesville_DOFP_2009	6.092	$6.10
Eagle Ford_DOFP_2009	3.793	$6.24

Conclusions

- Haynesville IP > Eagle Ford IP > Woodford IP > Fayetteville IP > Barnett IP
  - Haynesville Shale IP is considerably higher than other Shales due to
    - Higher reservoir pressure
    - Aggressive drilling and completion approach
- Production increased with time across all shale gas basins analyzed
  - Barnett Shale is the exception
  - Due to improvements in drilling, completion practices, stimulation designs, and knowledge gain over time
- Cotton Valley Sand has the steepest decline over time of all formations analyzed

Conclusions

- Barnett Shale had a flatter production decline trend
  - Barnett would not serve as an analog shale play for estimating production declines in other shale gas plays
  - Could be due to natural fractures, curvature, and stress
  - Vertical and horizontal wells exhibit similar decline profiles during first 2 years of production
- 'b' exponents greater than 1.0 are realistic in unconventional gas reservoirs
- Economics in our study areas
  - Barnett and Fayetteville are economical @ $4/MScf gas price at 10% discount rate
  - Haynesville, Eagle Ford, and Woodford are economical @ >$6/MScf at 10% discount rate

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