The Shale Revolution in North America: *Myths and Realities*

Beyond the Hype: Economics of Shale Gas in Europe
EU Parliament
Brussels, Belgium
May 14, 2013

J. David Hughes

Post Carbon Institute

Conventional Wisdom

- The United States is on the verge of Energy Independence thanks to the Shale "REVOLUTION".

- Shale Gas production will continue to grow for the foreseeable future (2040 at least) and prices will remain below $4.50/mcf for the next 10 years and below $6.00/mcf for the next 20 years.

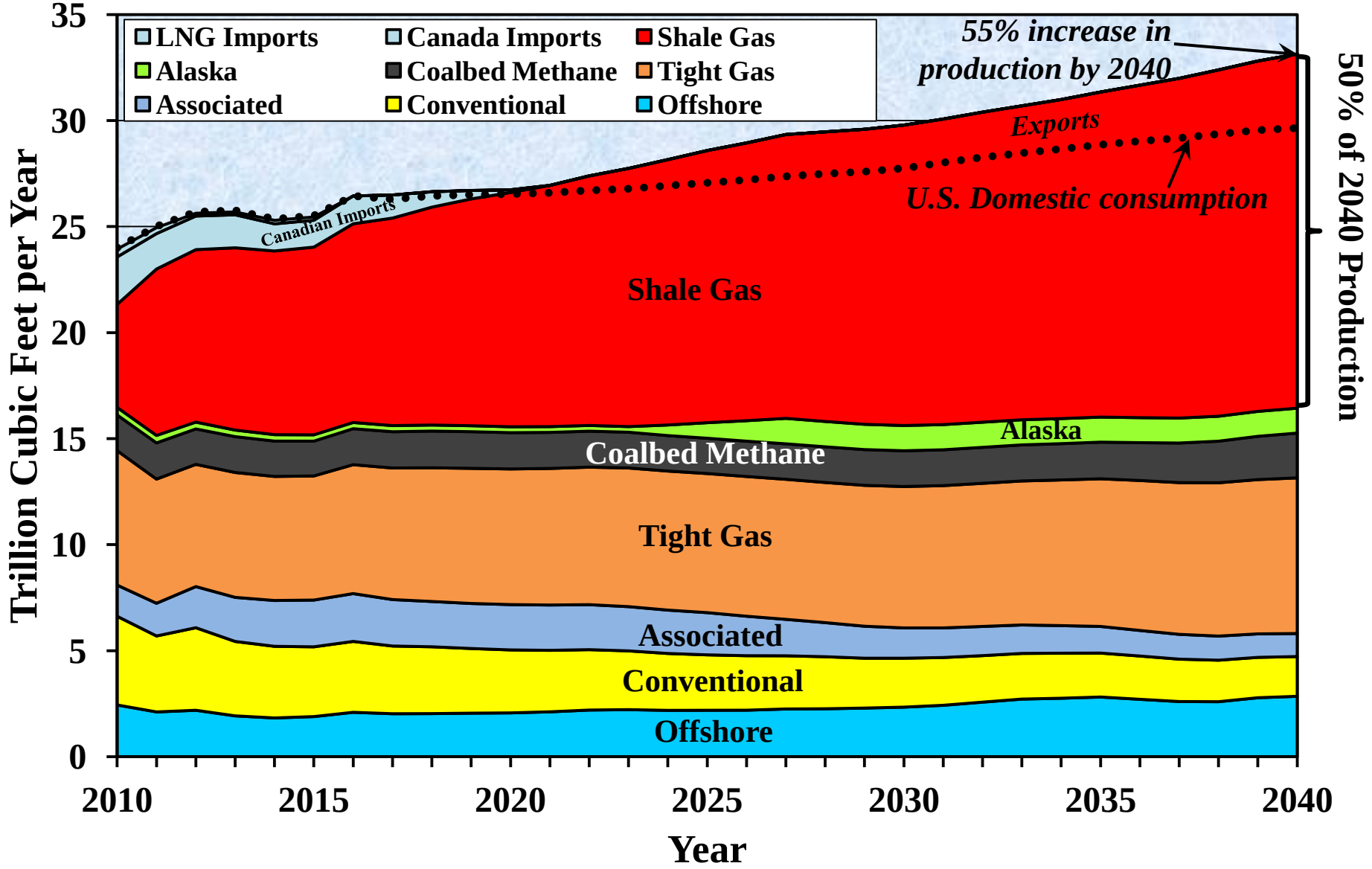
- Shale Gas can replace very substantial amounts of oil for transport and coal for electricity generation.

- The way is clear for U.S. LNG exports to monetize the shale bounty.

- Tight Oil will allow U.S. production to exceed that of Saudi Arabia and U.S. imports will shrink to zero.

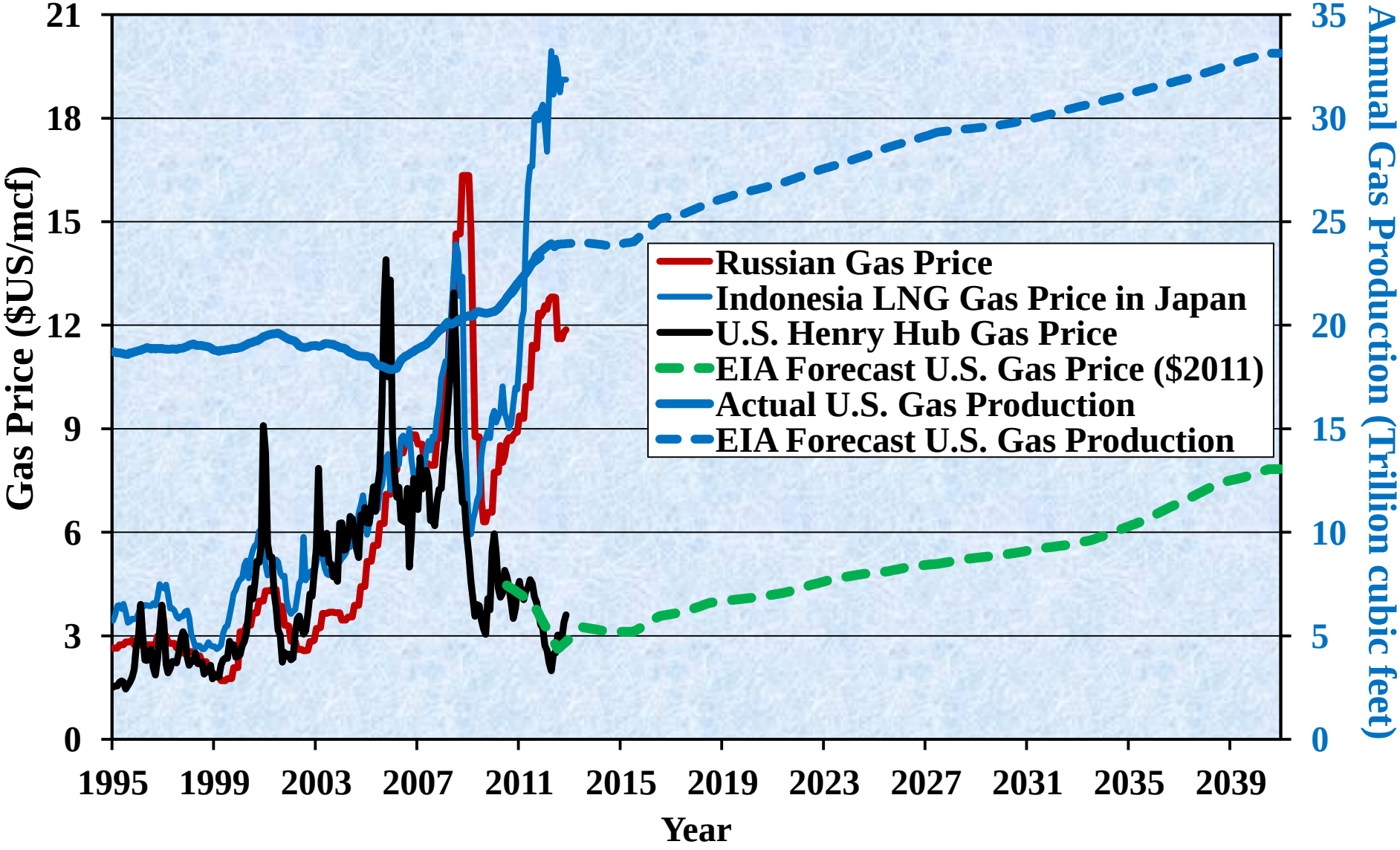
- The Shale "REVOLUTION" will provide Europe with a growing supply cheap gas for the foreseeable future.

U.S. Natural Gas Supply Projection by Source, 2010-2040, EIA Reference Case 2013



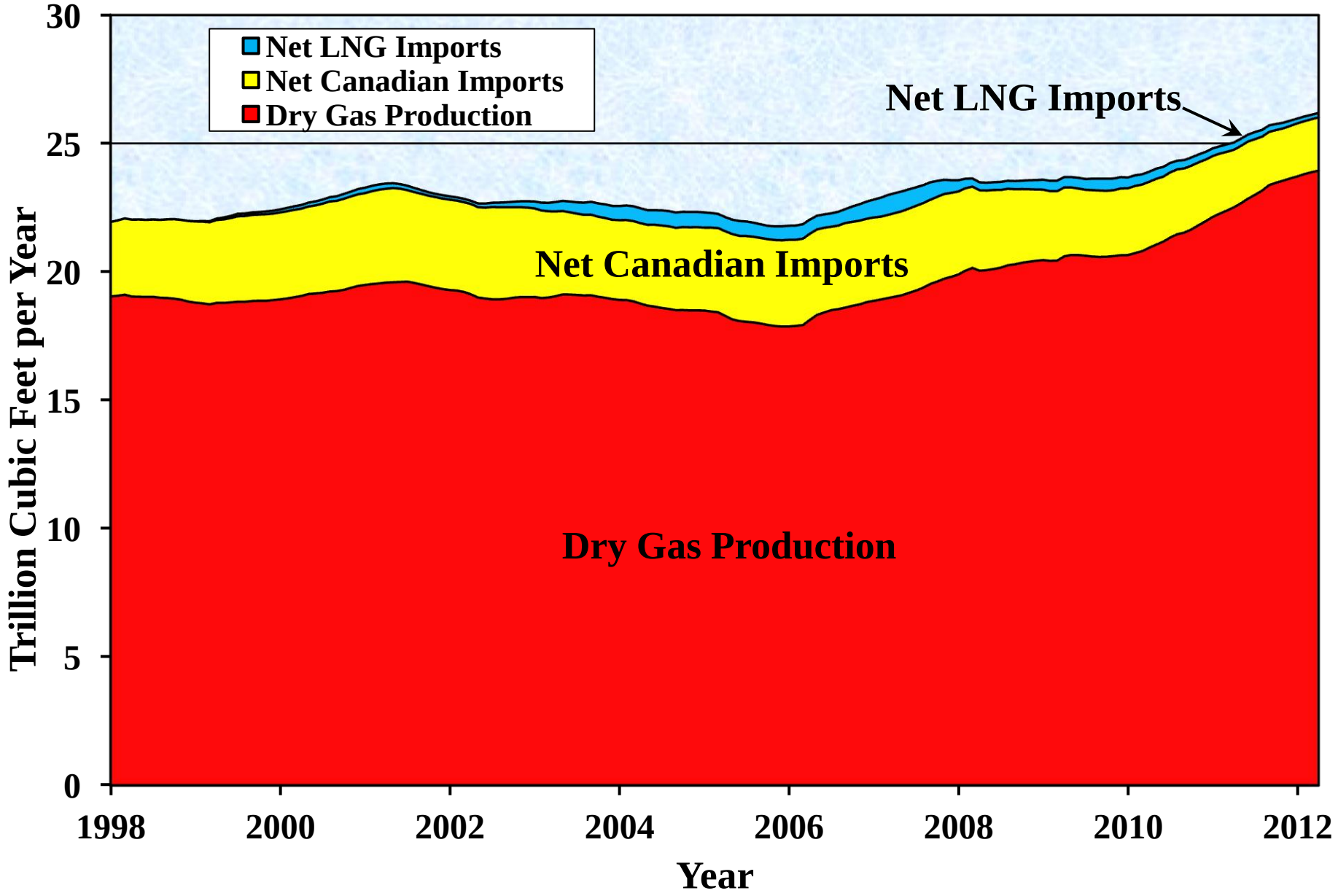
(data from EIA Annual Energy Outlook 2013, Tables 13 and 14, http://www.eia.gov/forecasts/aeo/er/excel/yearbyyear.xlsx

EIA Projections of Gas Price and U.S. Production Compared to History, 1995-2040



(data from EIA Annual Energy Outlook 2013, EIA, 2012; International Monetary Fund)

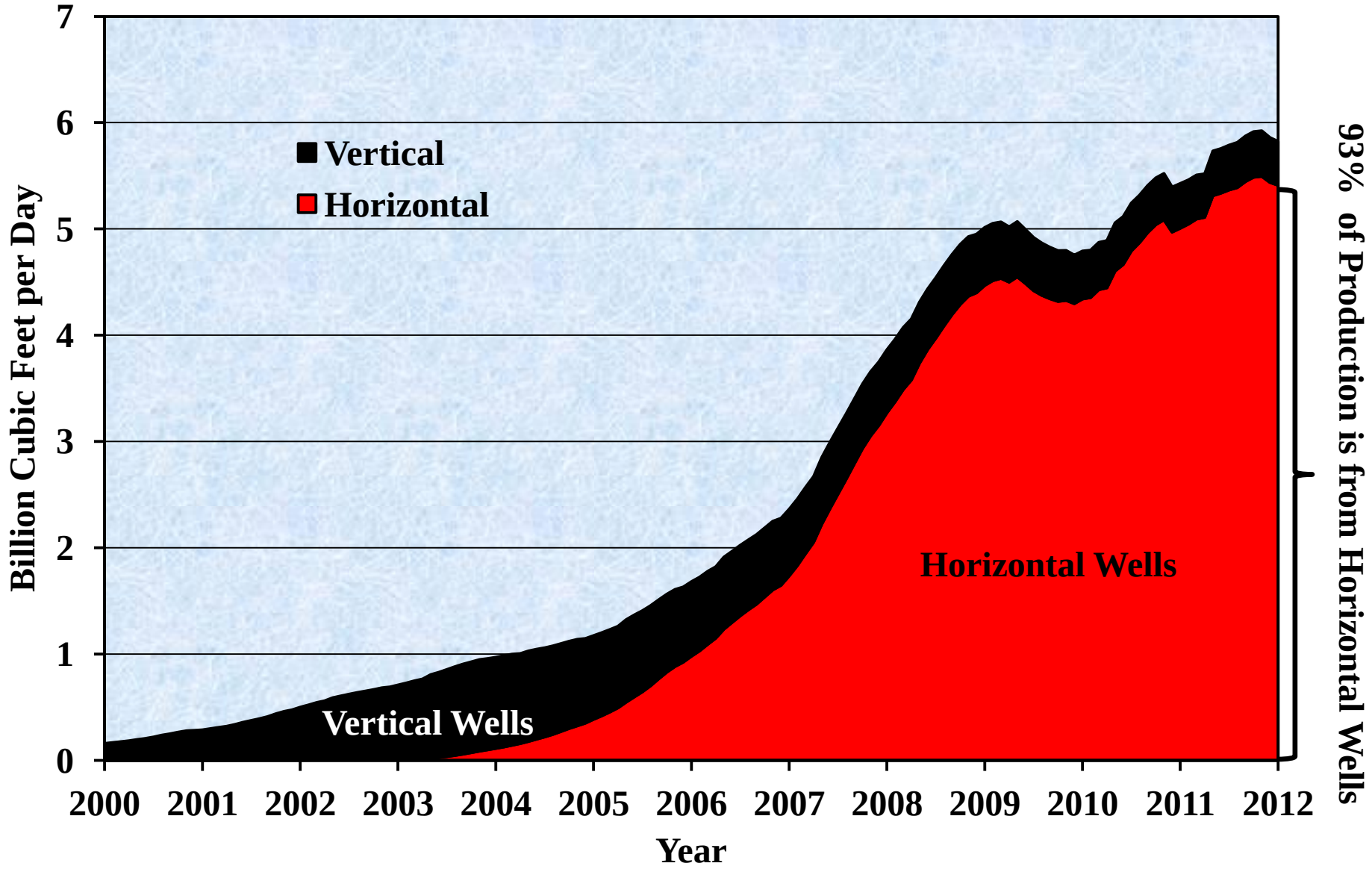
U.S. Gas Production and Imports, 1998-2012



(data from EIA current to August, 2012)

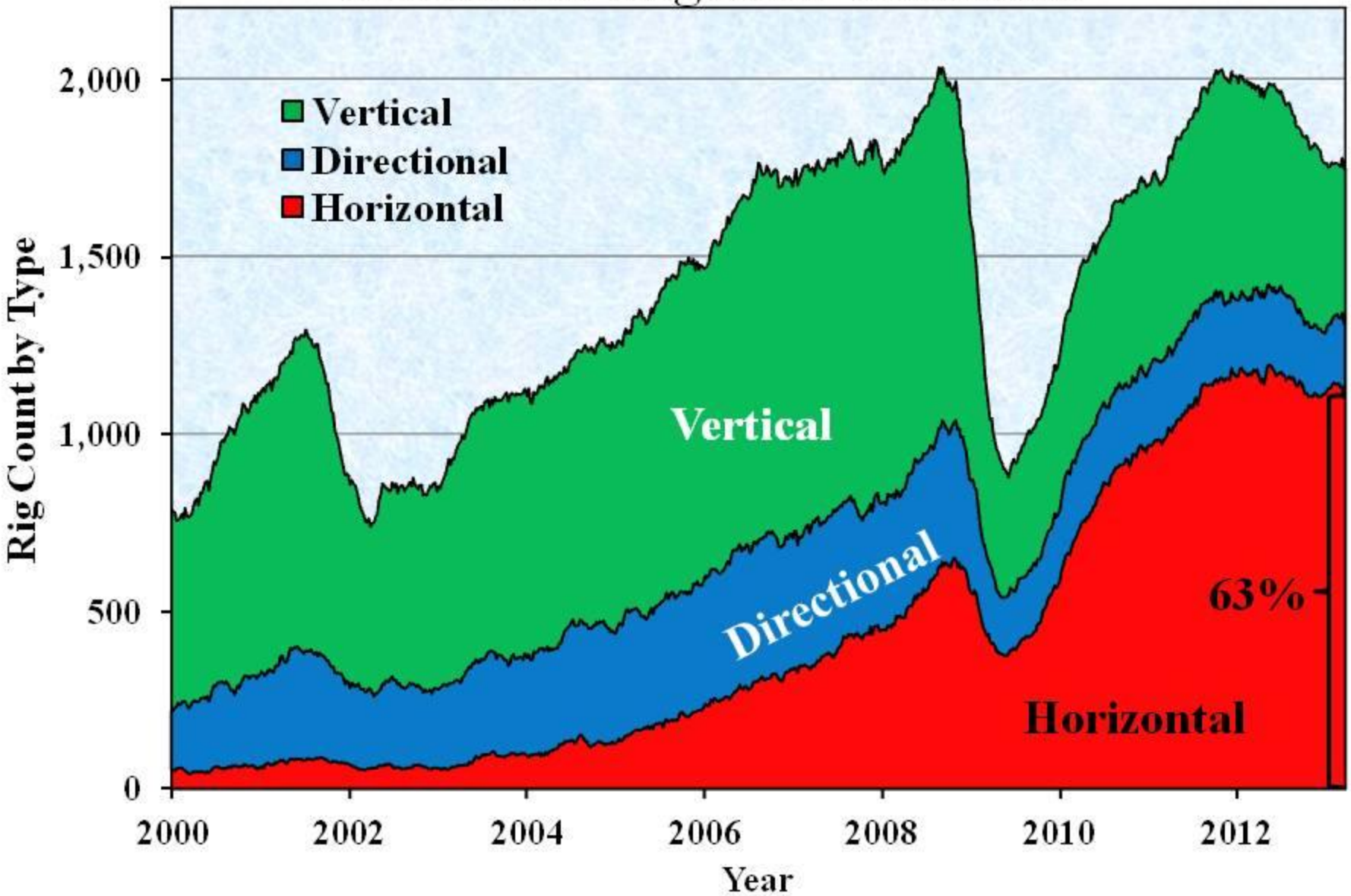

Lower 48 states shale plays
Niobrara*
Montana Thrust Belt
Heath**
Bakken***
Cody
Williston Basin
Big Horn Basin
Powder River Basin
Gammon
Hilliard-Baxter-Mancos
Mowry
Greater Green River Basin
Niobrara*
Park Basin
Uinta Basin
Manning Canyon
Mancos
Hermosa
Piceance Basin
Denver Basin
San Joaquin Basin
Monterey-Temblor
Paradox Basin
Pierre
Lewis
San Juan Basin
Raton Basin
Monterey
Santa Maria, Ventura, Los Angeles Basins
Excello-Mulky
Cherokee Platform
Woodford
Anadarko Basin
Ardmore Basin
Palo Duro Basin
Bend
Avalon-Bone Spring
Permian Basin
Barnett-Woodford
Marfa Basin
Barnett
Ft. Worth Basin
Eagle Ford
Pearsall
Western Gulf
Forest City Basin
Fayetteville
Arkoma Basin
Michigan Basin
Antrim
Illinois Basin
New Albany
Chattanooga
Black Warrior Basin
Floyd-Neal
TX-LA-MS Salt Basin
Tuscaloosa
Haynesville-Bossier
Appalachian Basin
Devonian (Ohio)
Marcellus
Utica
Conasauga
Valley & Ridge Province
Miles
0 100 200 300 400
N
Shale plays
Current plays
Prospective plays
Stacked plays
Shallowest/ youngest
Intermediate depth/ age
Deepest/ oldest
Basins
* Mixed shale & chalk play
** Mixed shale & limestone play
***Mixed shale & tight dolostone-siltstone-sandstone
eia

Barnett Shale Production by Well Type, 2000-2012, Illustrating Impact of Horizontal Drilling Technology



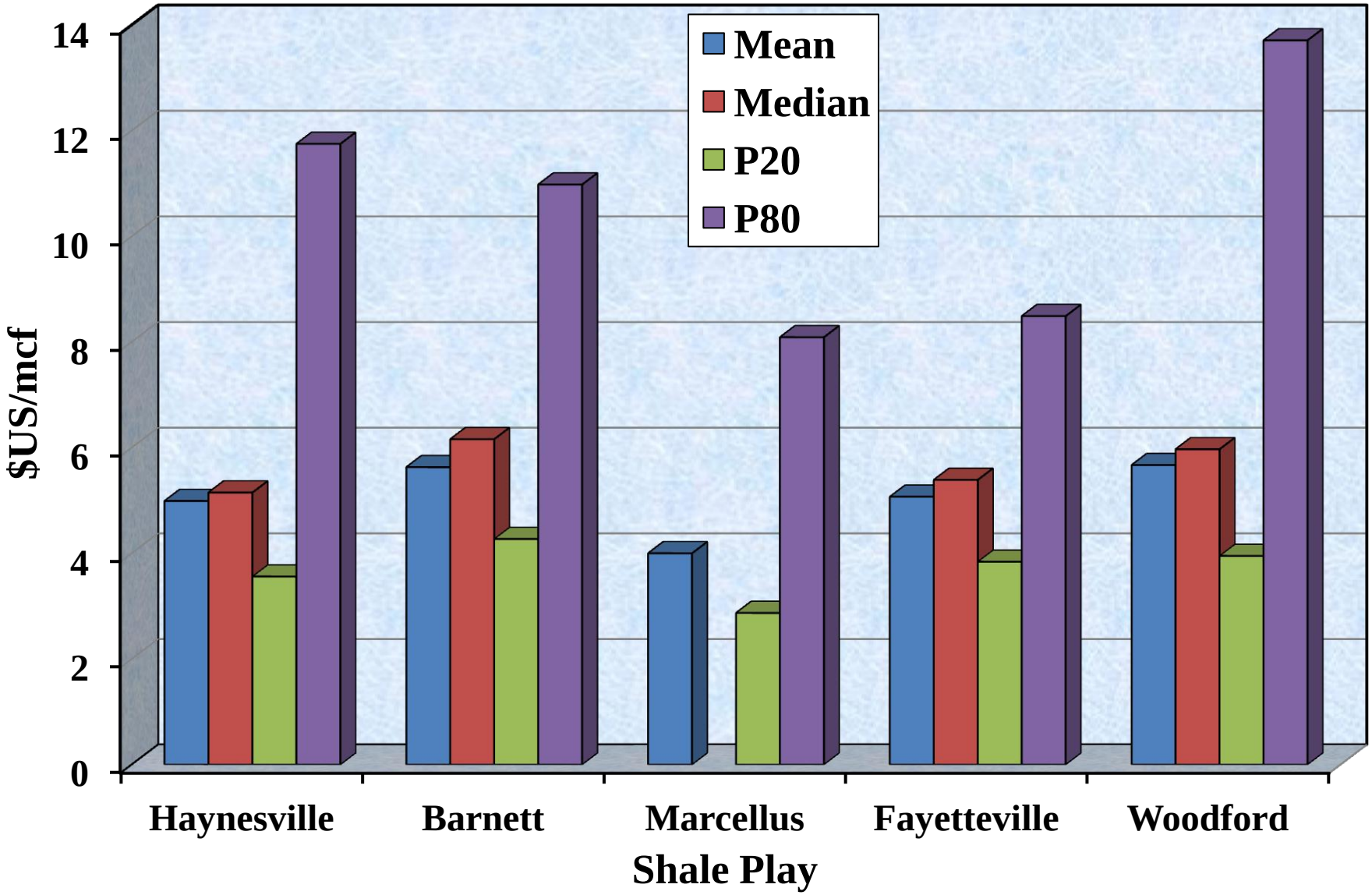
(data from DIdesktop, June, 2012, fitted with 5 month centered moving average including data up to March, 2012)

U.S. Rig Count by Type, 2000-2013
Horizontal Rigs now Dominate



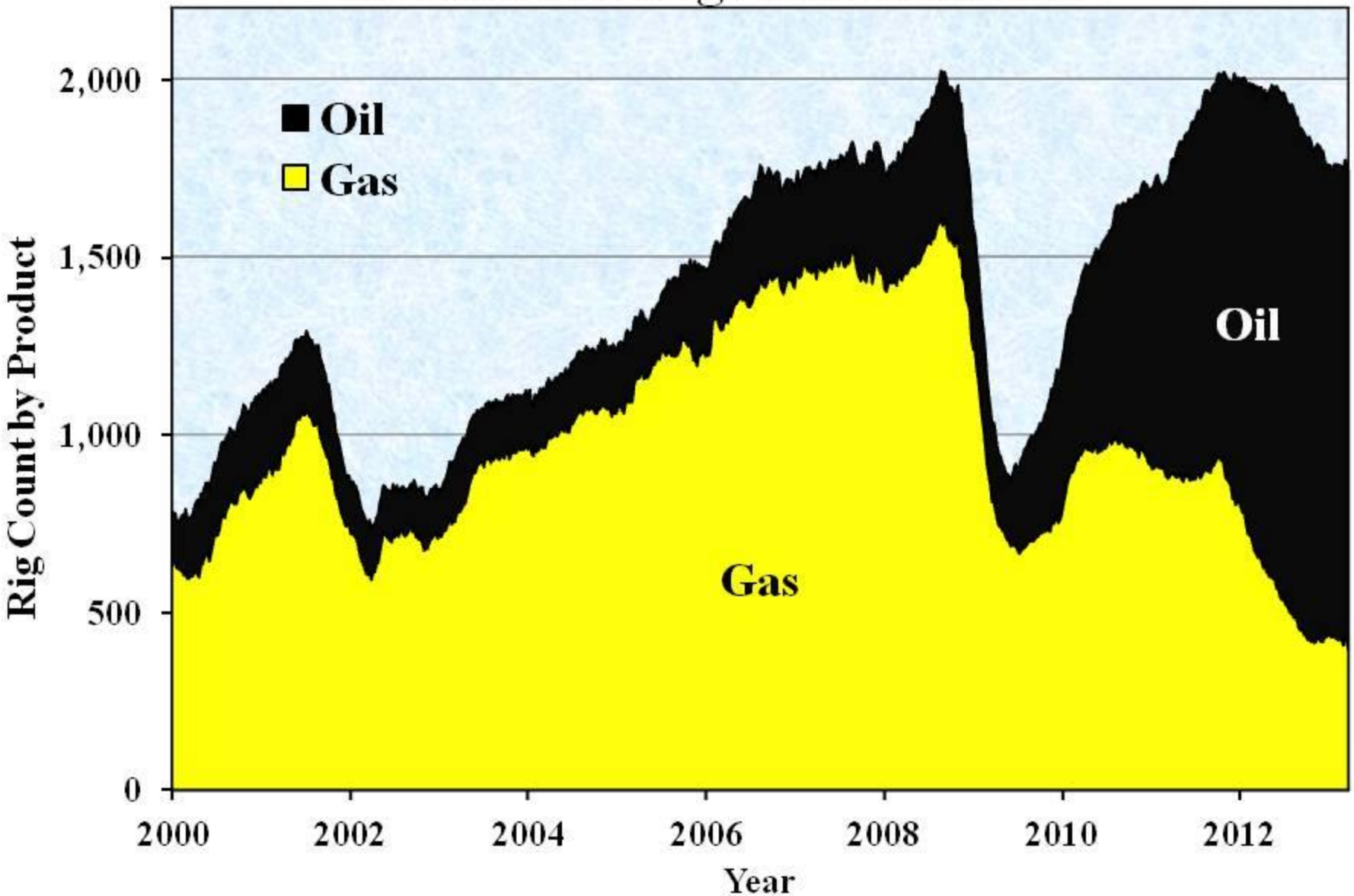
(data from Baker-Hughes, March, 2013)

Breakeven Gas Price by Shale Play for a 10% Rate of Return



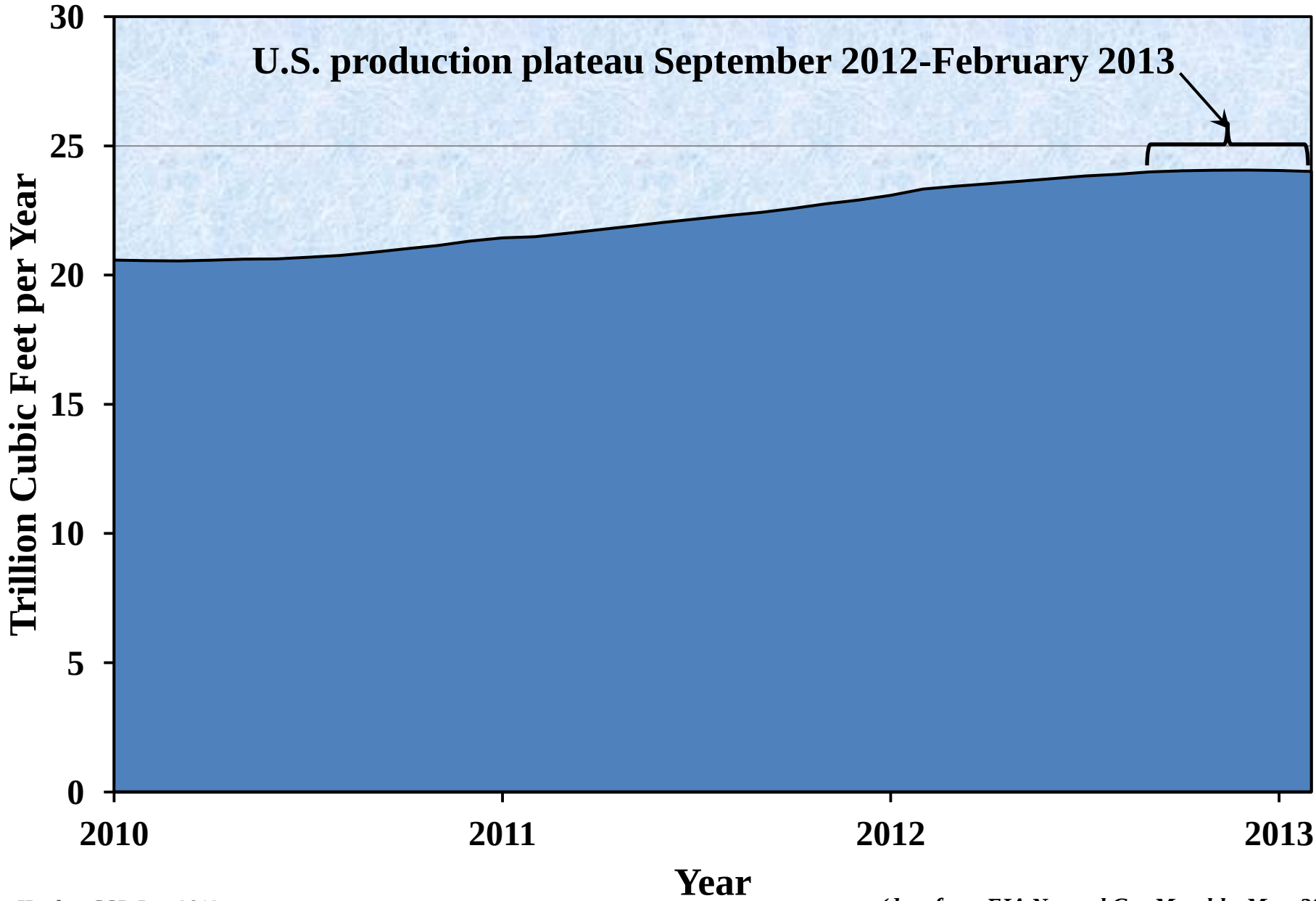
(data from Jacoby et al., Economics of Energy and Environmental Policy, vol. 1, no.1, 2012)

U.S. Rig Count by Product, 2000-2013
Oil-Directed Rigs now Dominate



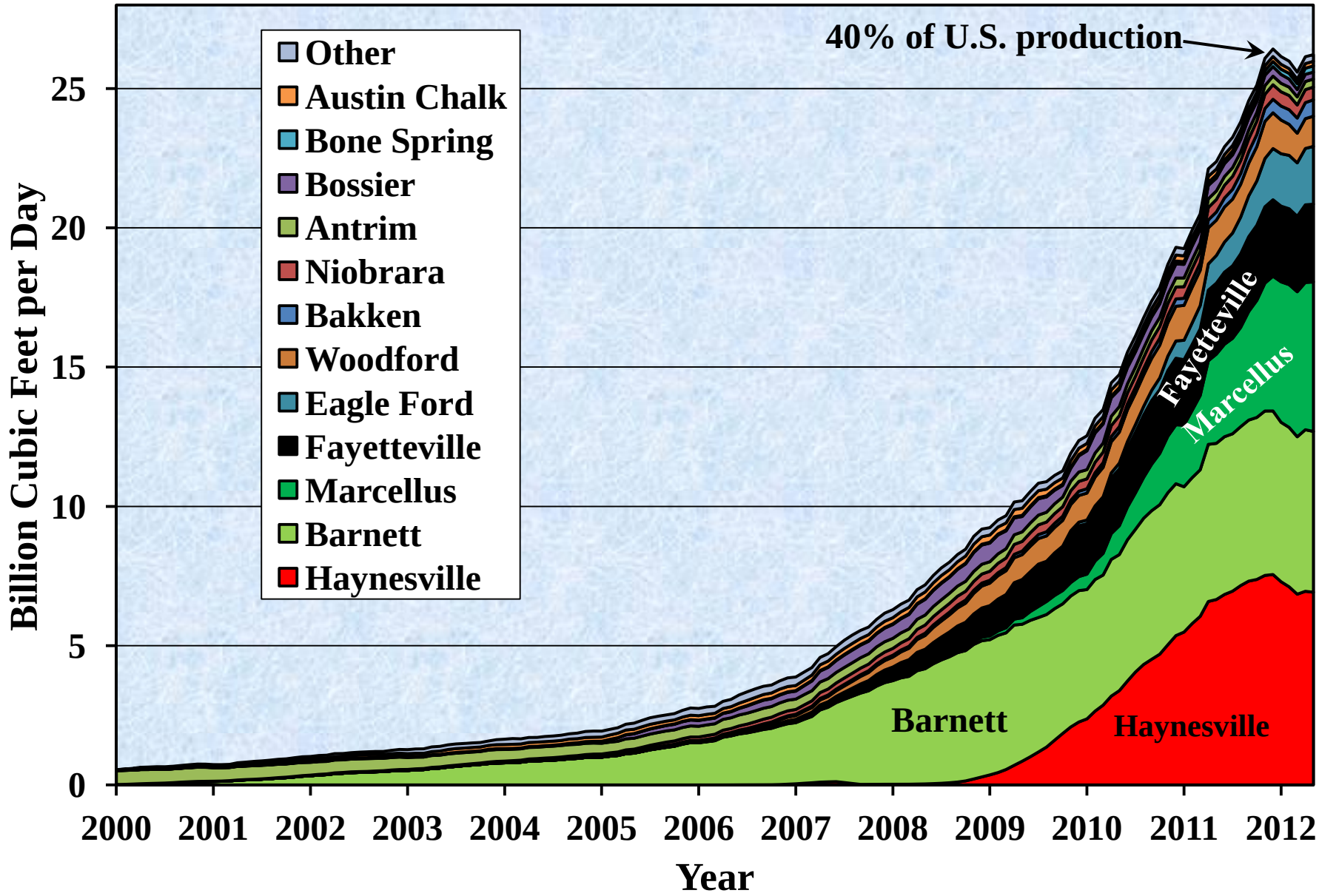
(data from Baker-Hughes, March, 2013)

U.S. Dry Gas Production, 2010-2013



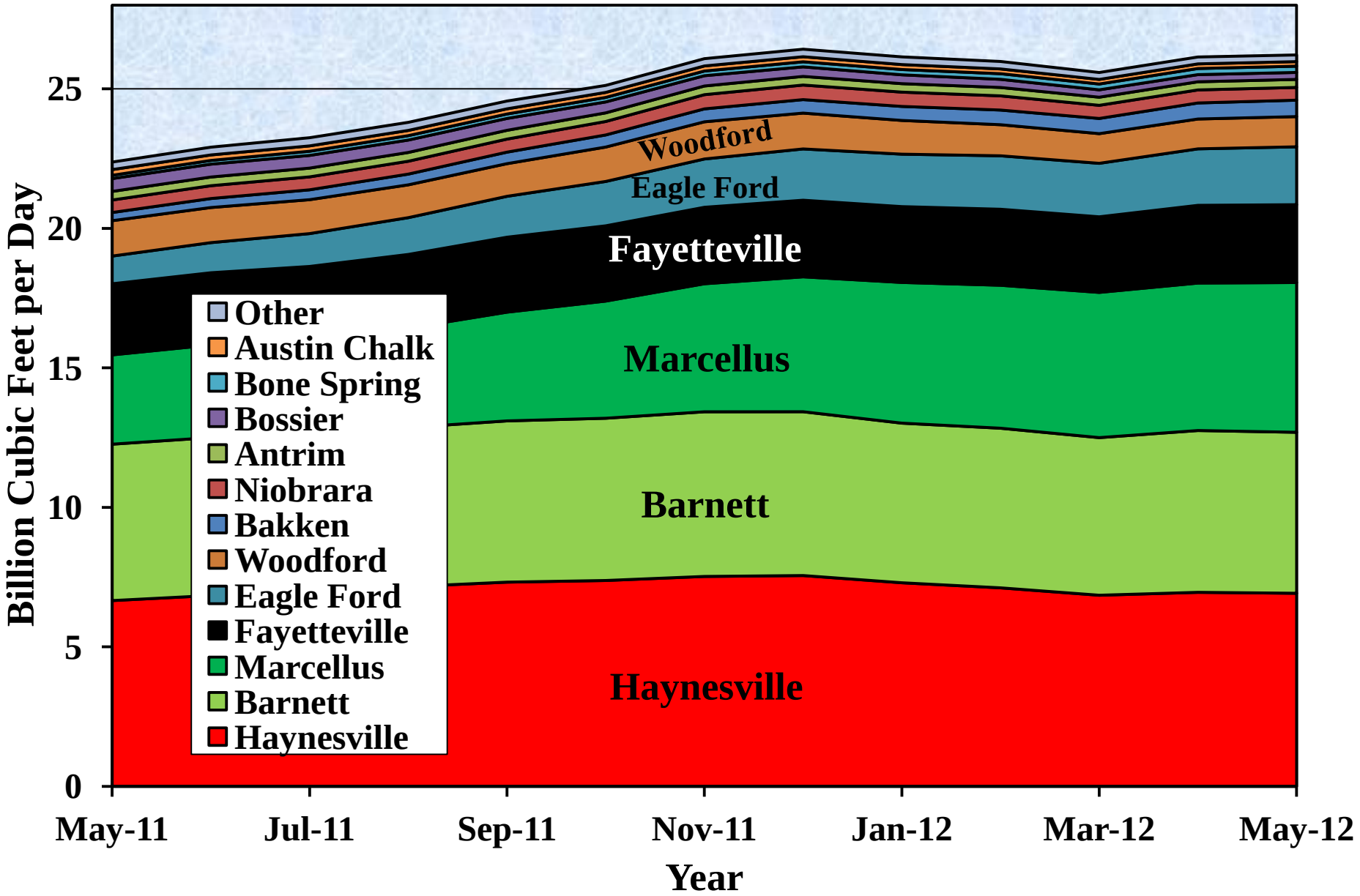
(data from EIA Natural Gas Monthly, May, 2013)

Shale Gas Production by Play, 2000-2012



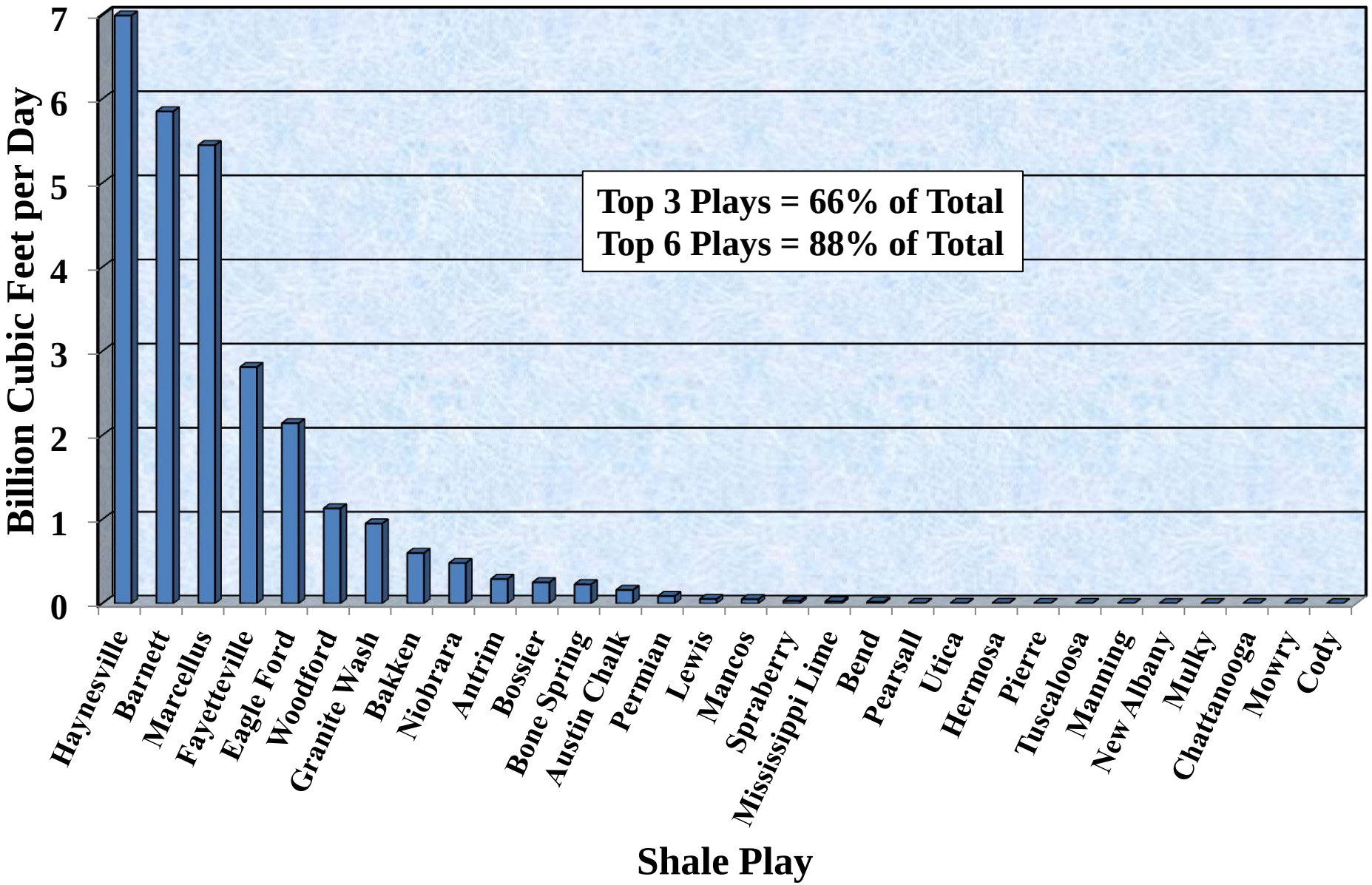
(data from DIdesktop, September, 2012, fitted with 3 month centered moving average including data up to June, 2012)

Shale Gas Production by Play, May 2011 – May 2012



(data from DI Desktop, HPDI, September, 2012)

Shale Gas Production by Play



(data from DI Desktop, September, 2012, for production in most cases through May-June, 2012)

The Shale Play Life Cycle

- Discovery followed by leasing frenzy.

- Drilling boom follows to meet "held-by-production" lease requirements.

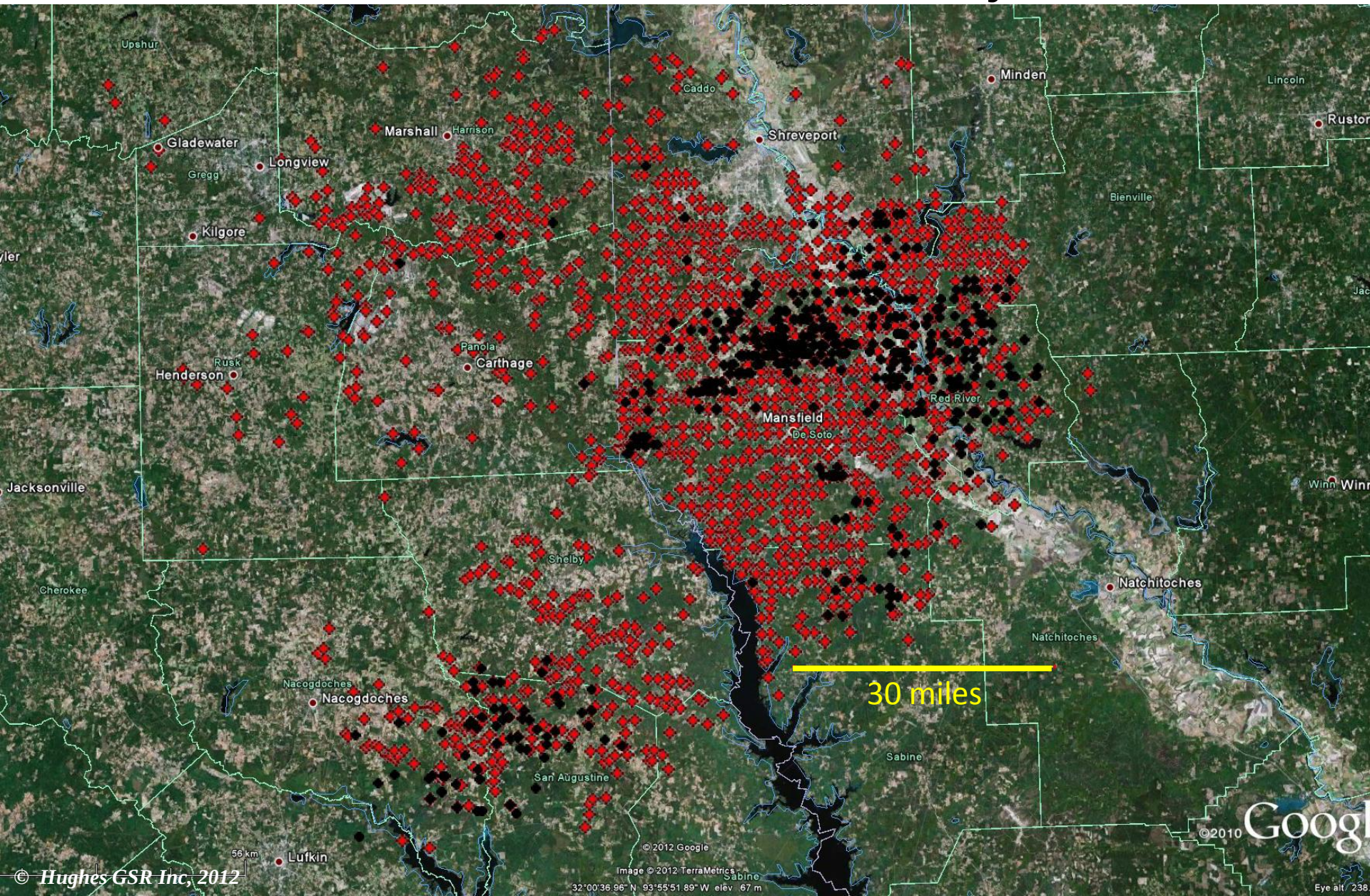
- Sweet spots identified, targeted and drilled off.

- Gas production rises rapidly and is maintained for cash-flow despite uneconomic full-cycle costs.

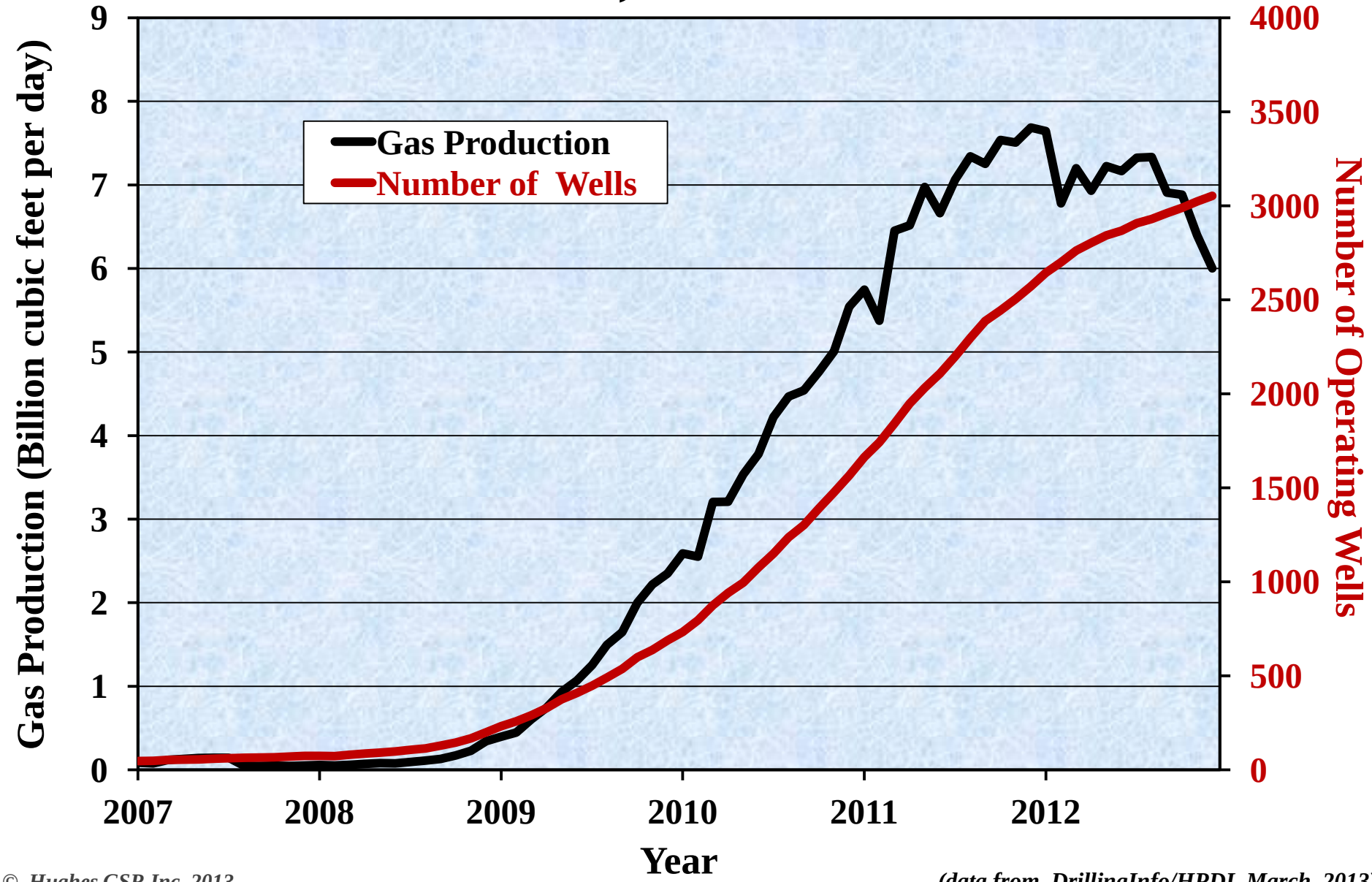
- Sweet spots become saturated and well quality and field production decline.

- Plays like the Haynesville become middle aged after just five years.

Haynesville Well Quality - Top 20% with Highest One Month Production of >10989 mcf/day in black

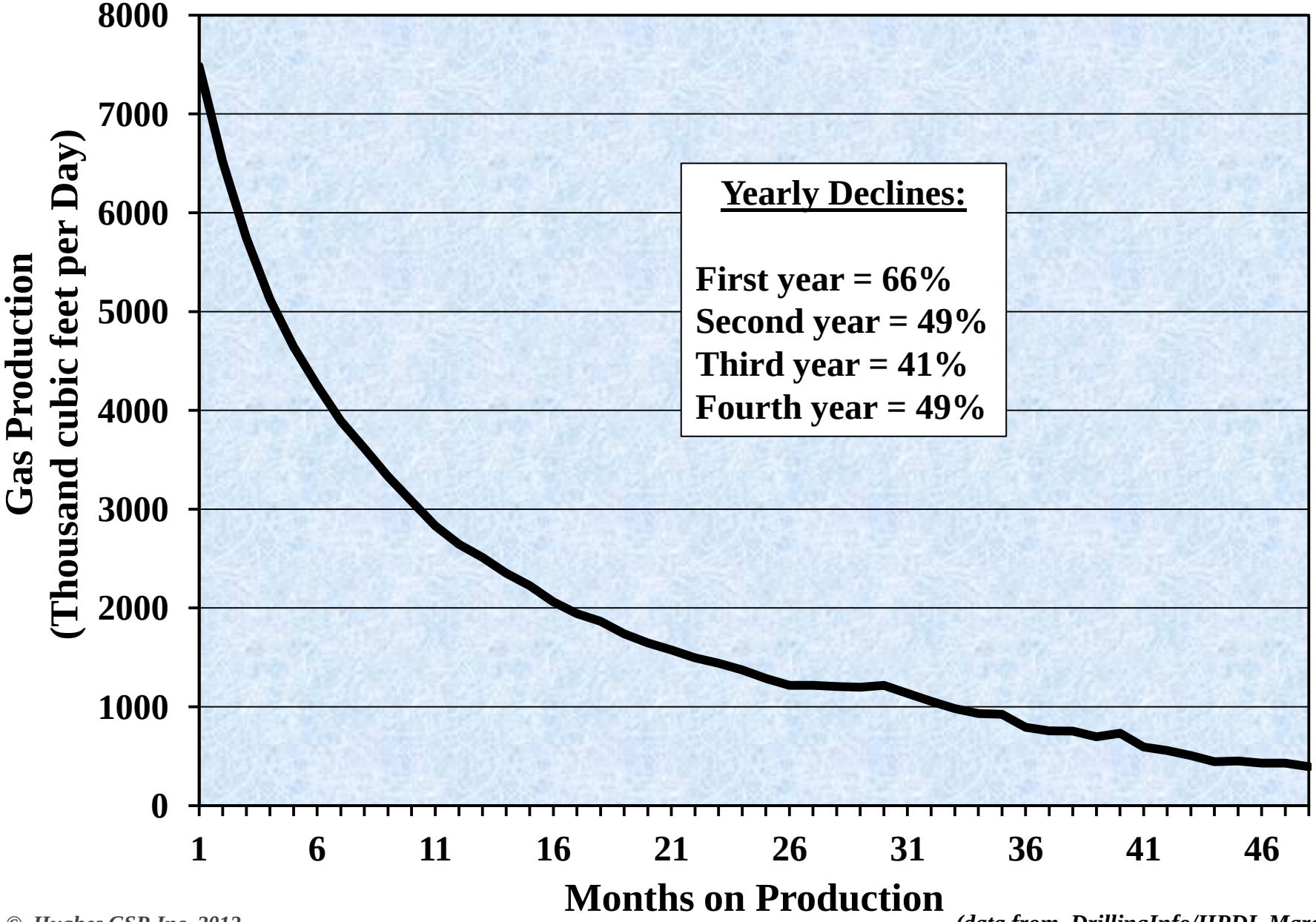


Haynesville Gas Production and Number of Operating Wells, 2007-2012



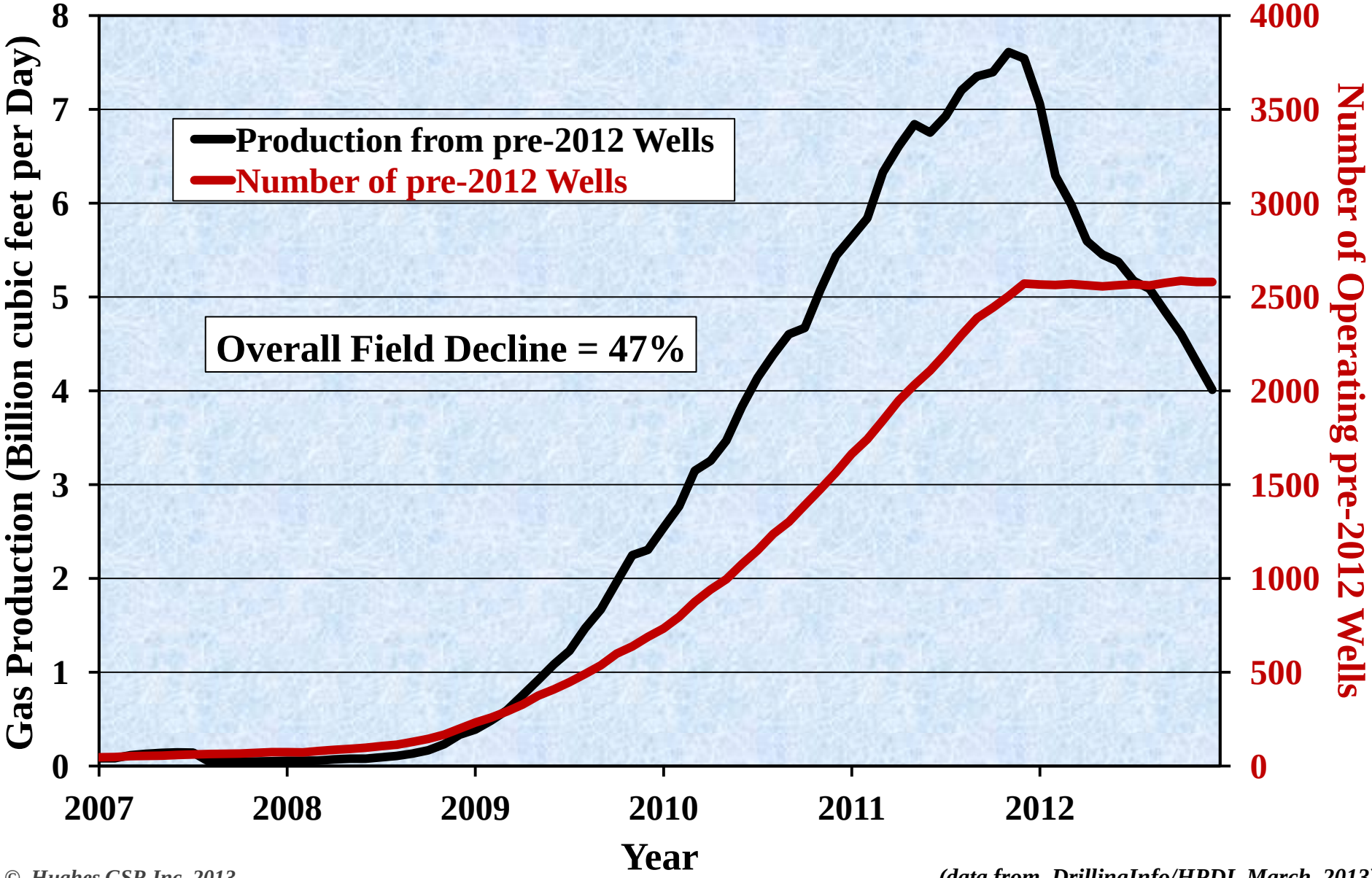
(data from DrillingInfo/HPDI, March, 2013)

Haynesville Type Gas Well Decline Curve



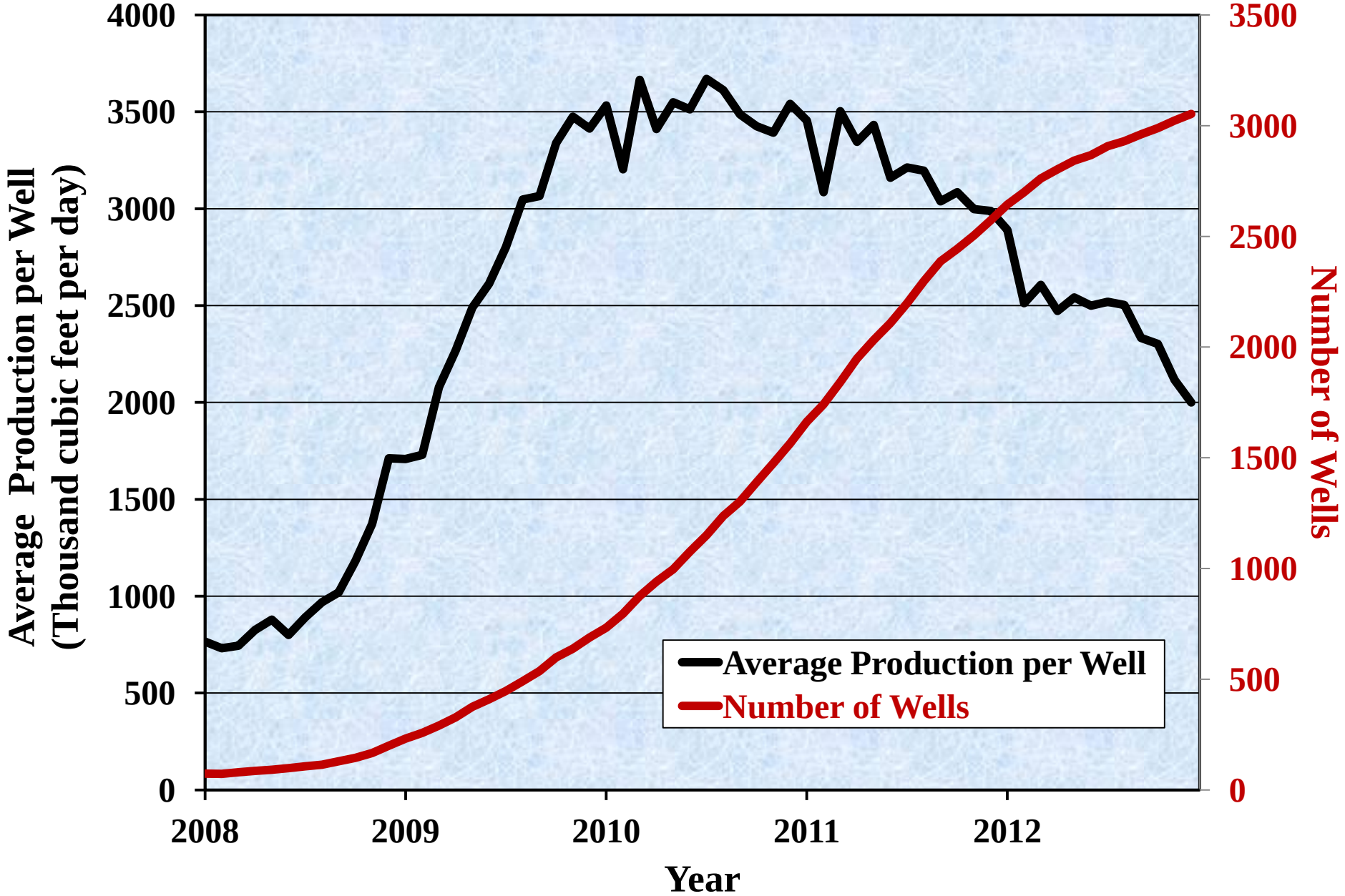
(data from DrillingInfo/HPDI, March, 2013)

Overall Field Decline for Haynesville Gas Production based on Production Decline from pre-2012 Wells



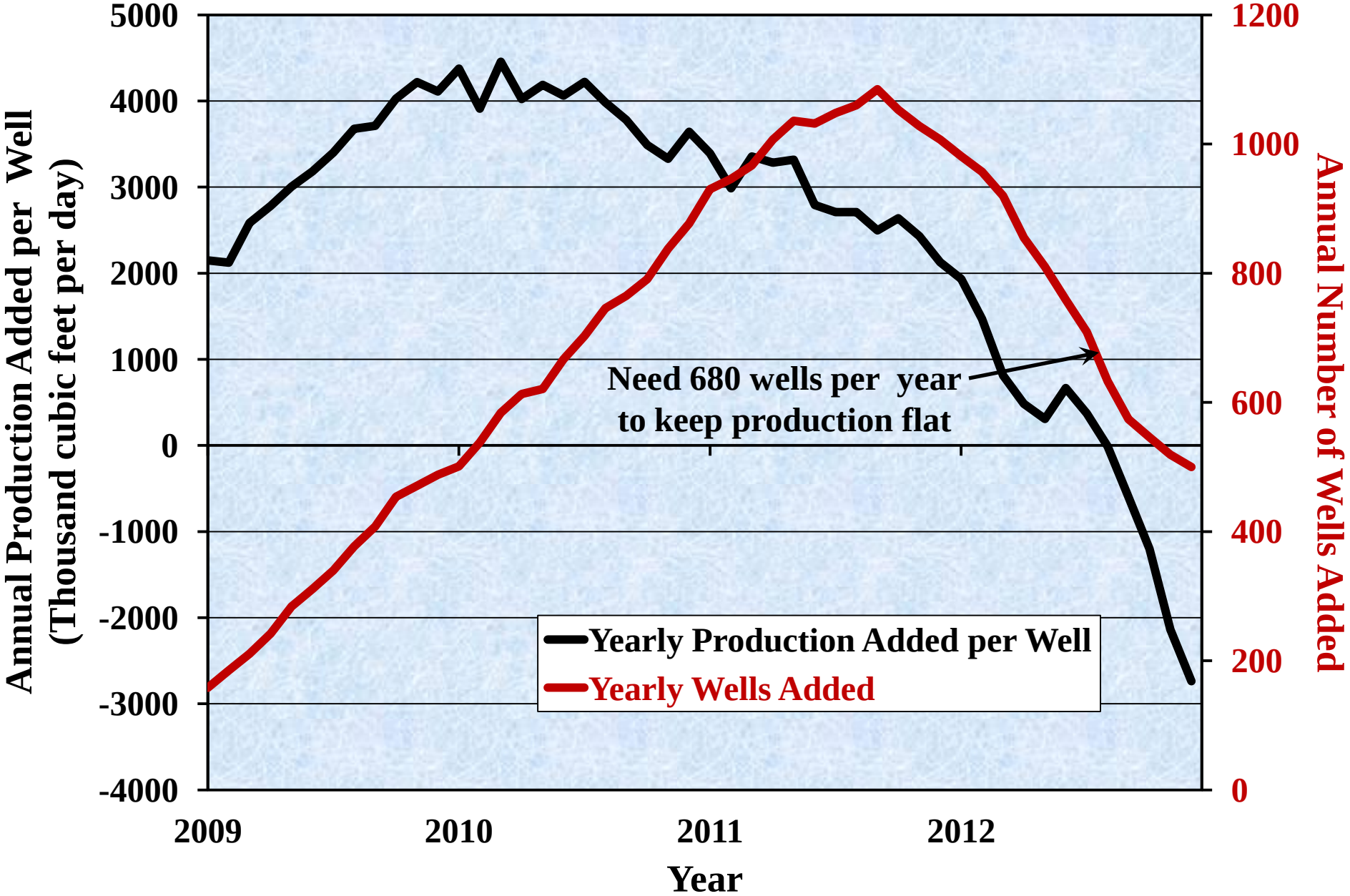
(data from DrillingInfo/HPDI, March, 2013)

Haynesville Average Production per Well



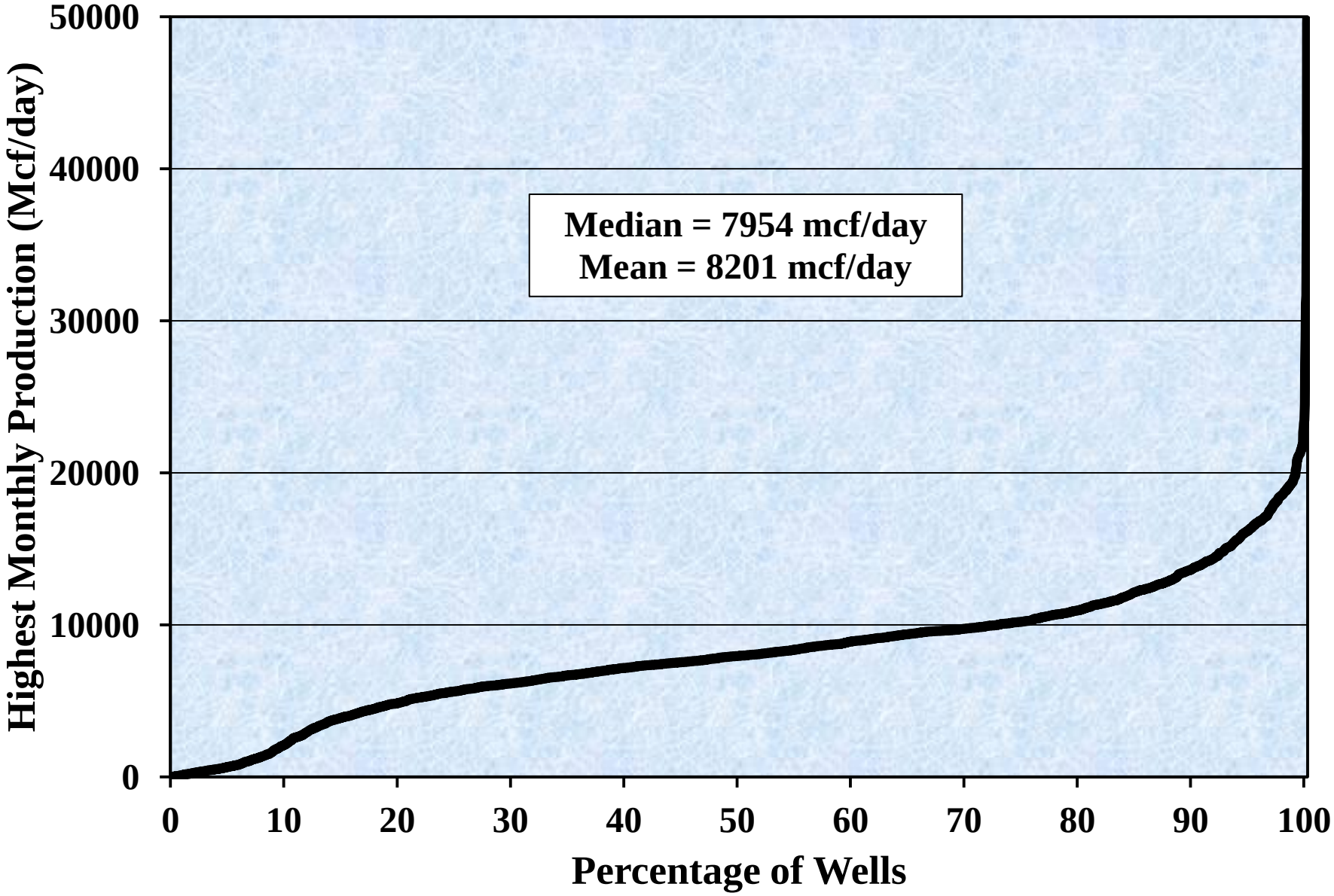
(data from DrillingInfo/HPDI, March, 2013)

Haynesville Annual Production Added per New Well



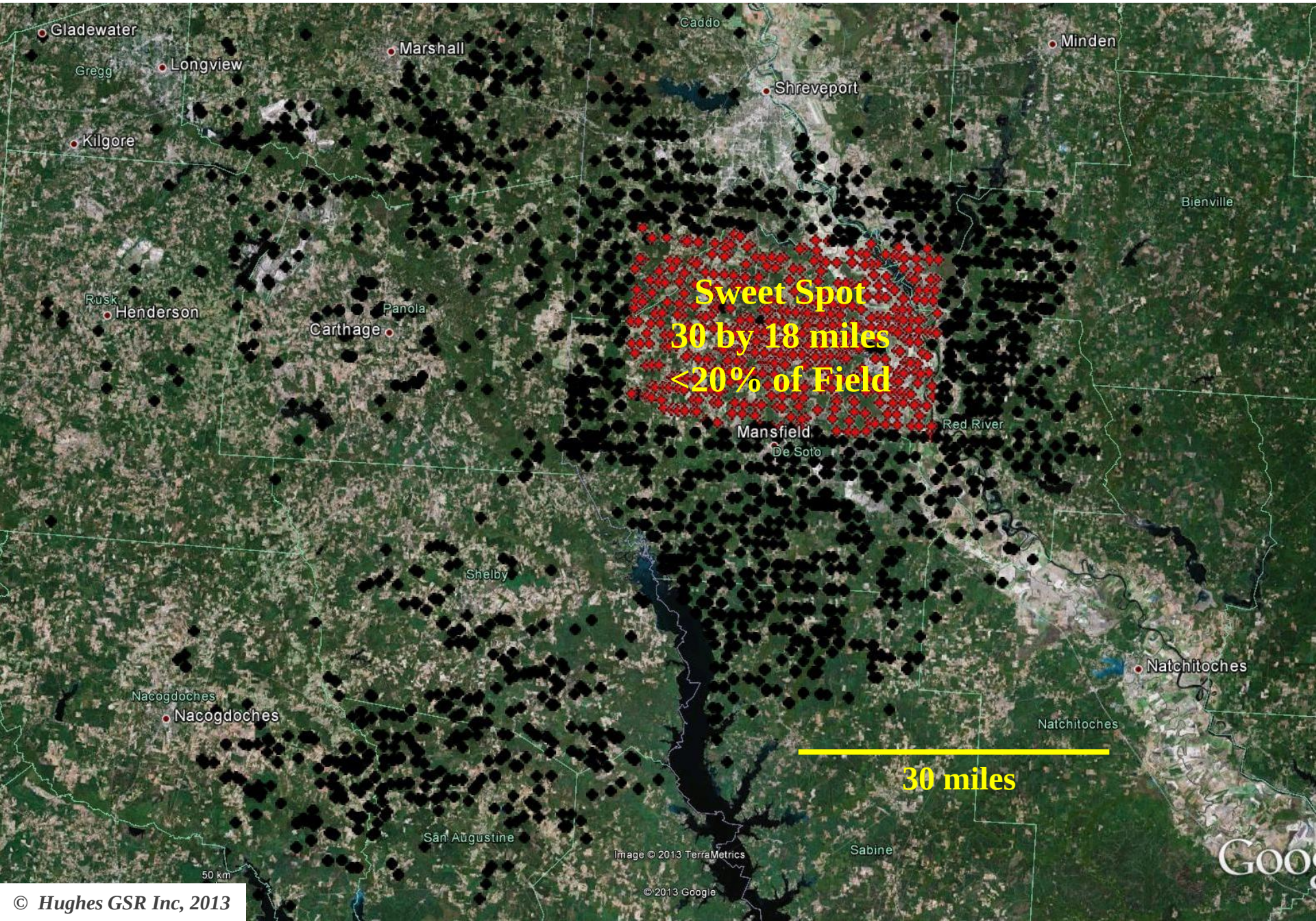
(data from DrillingInfo/HPDI, March, 2013)

Haynesville Well Quality
Highest One Month Gas Production from Individual Wells

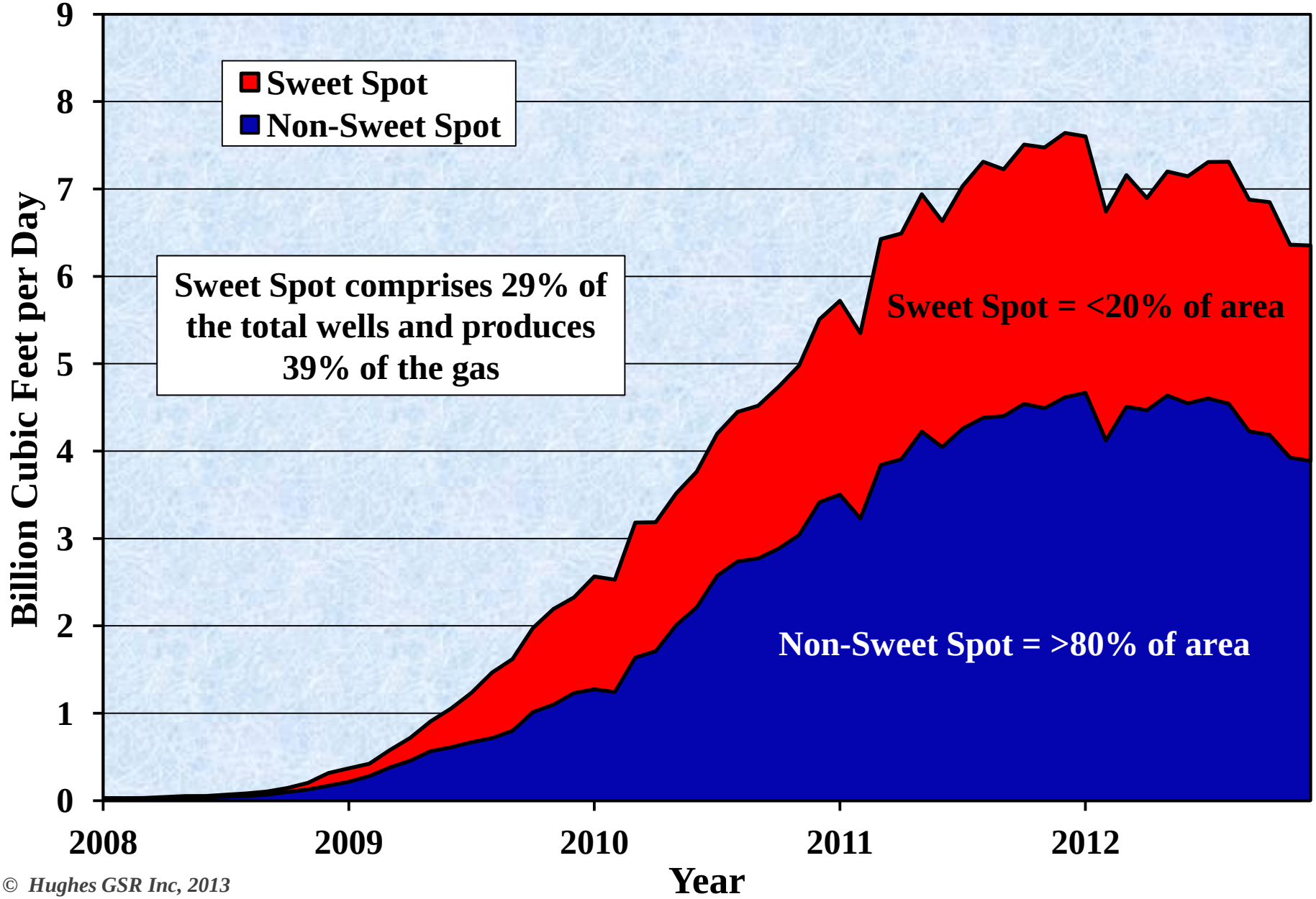


(data from DI Desktop, HPDI, September, 2012)

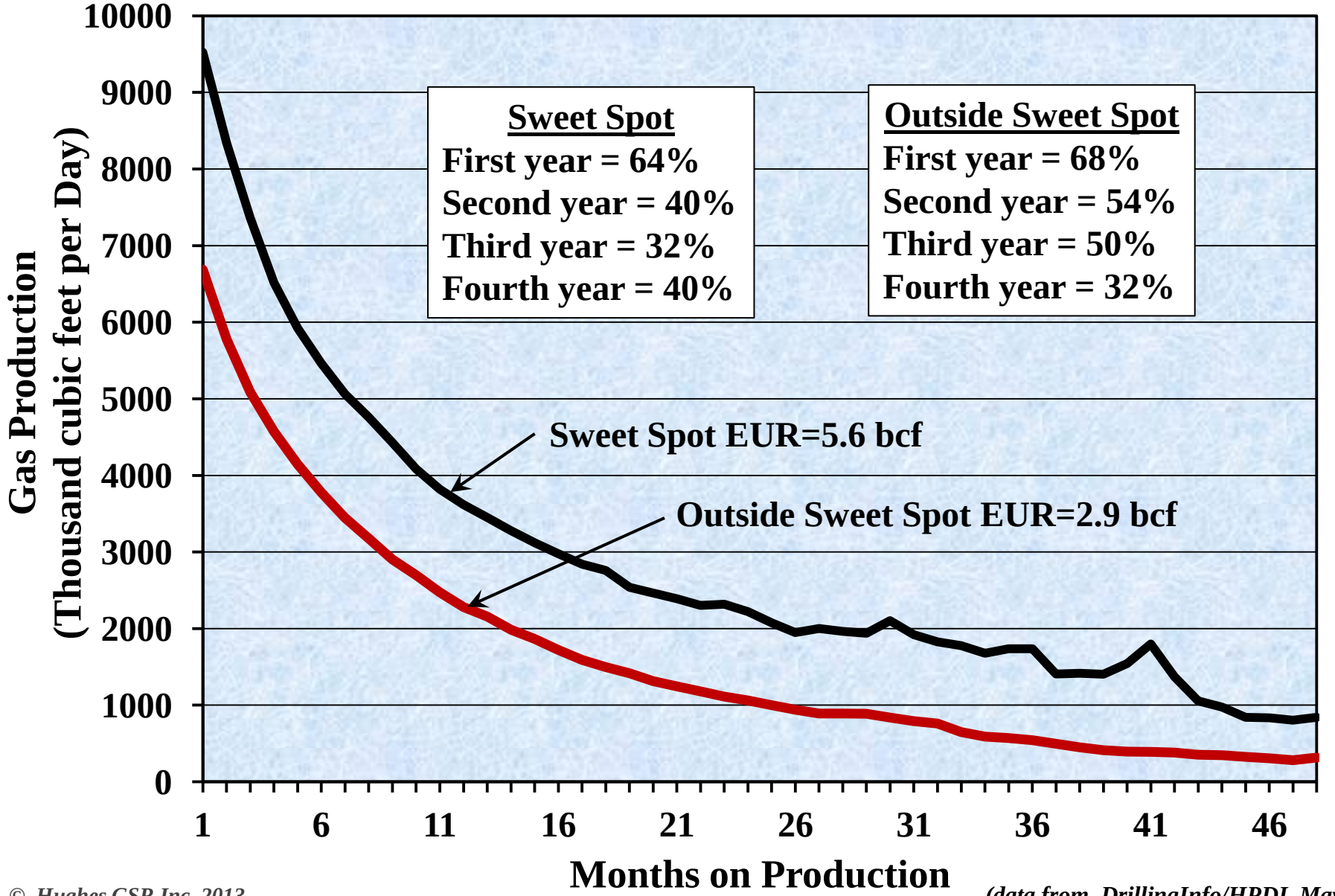
Haynesville Operating Wells with Sweet Spot (Red)



Haynesville Production from Sweet Spot vs Non-Sweet Spot Areas



Haynesville Type Gas Well Decline Curves
Sweet Spot vs Areas outside Sweet Spot



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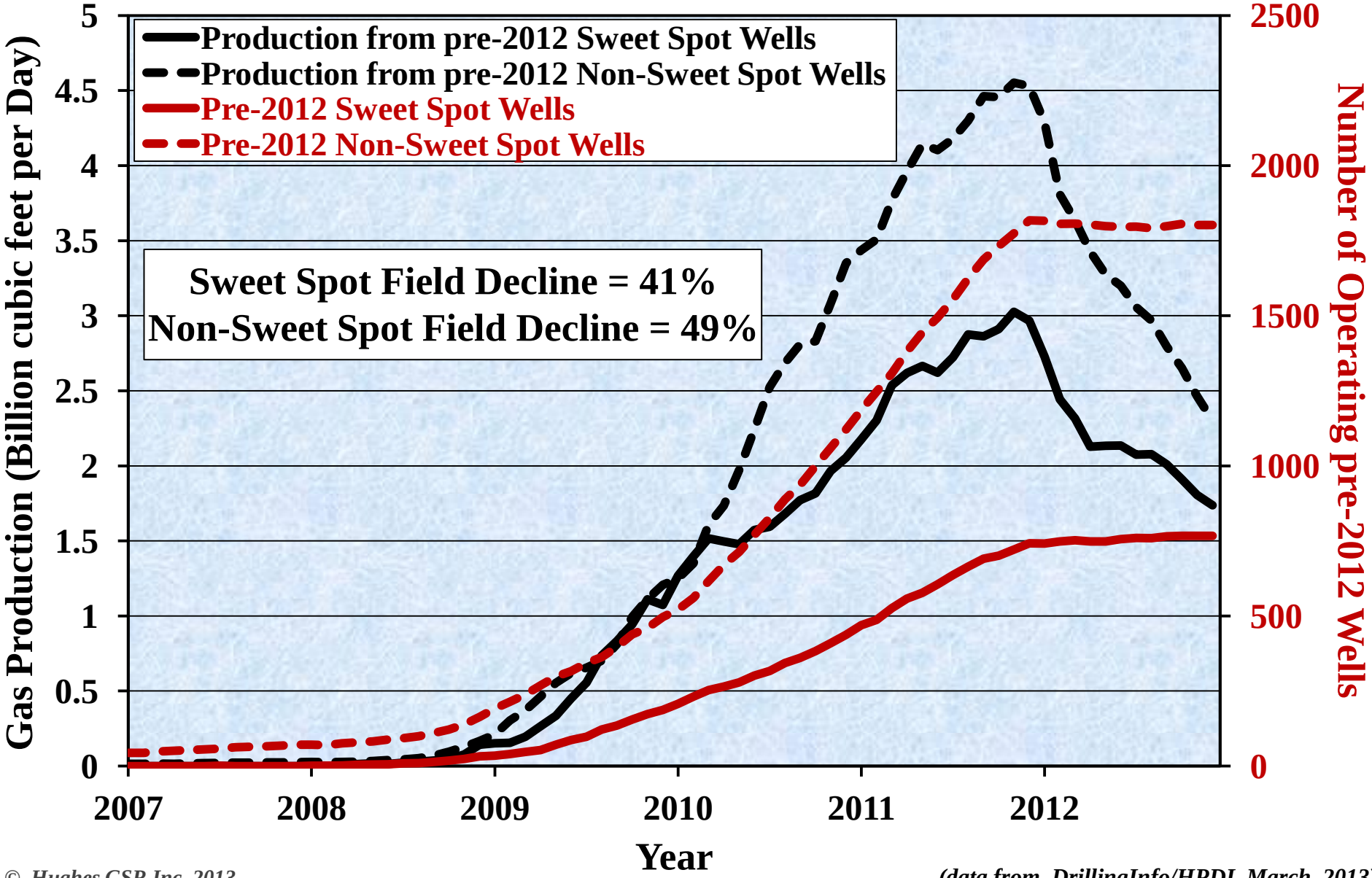
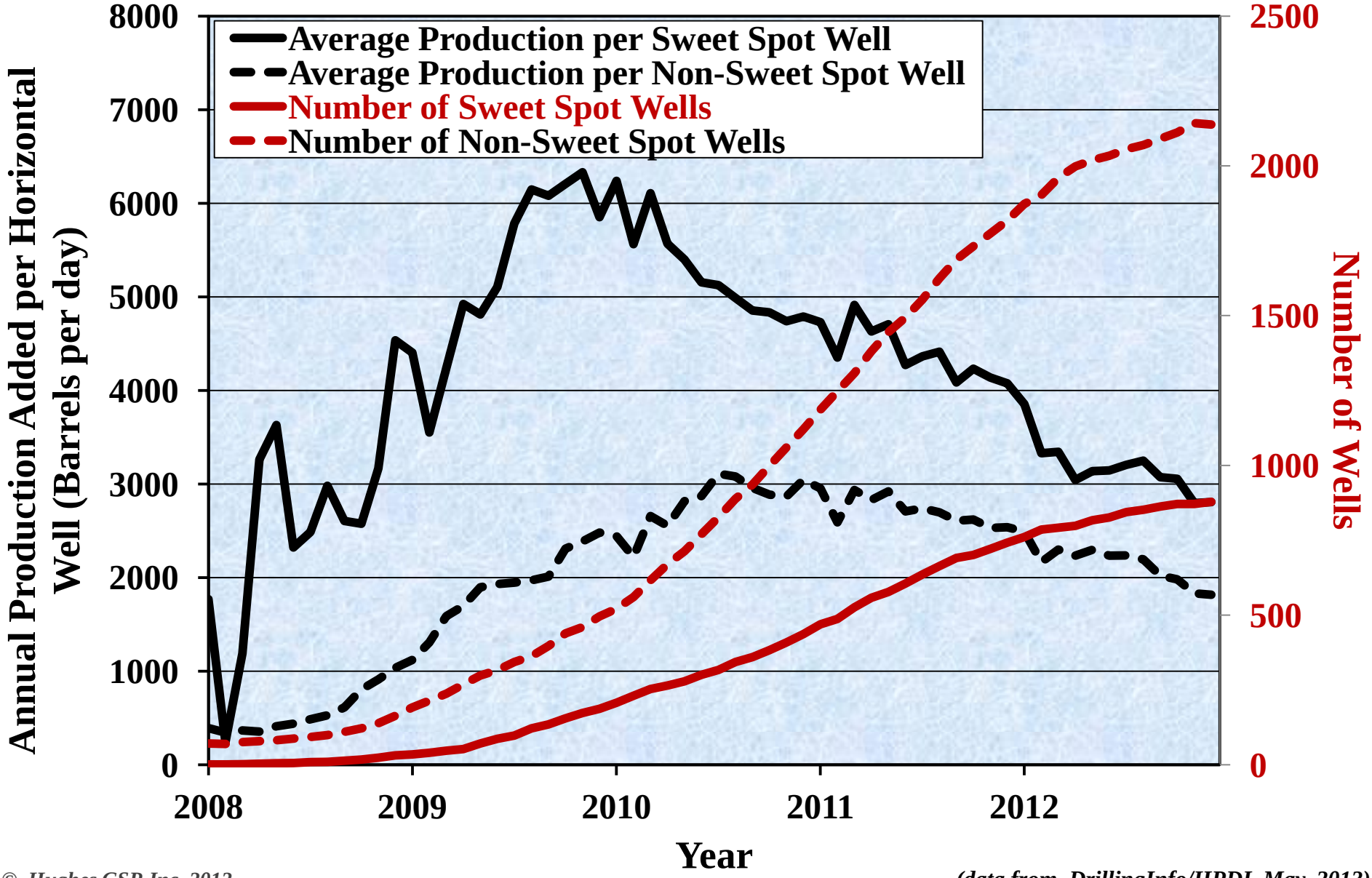
Overall Field Decline for Haynesville Gas Production based on Production Decline from pre-2012 Wells



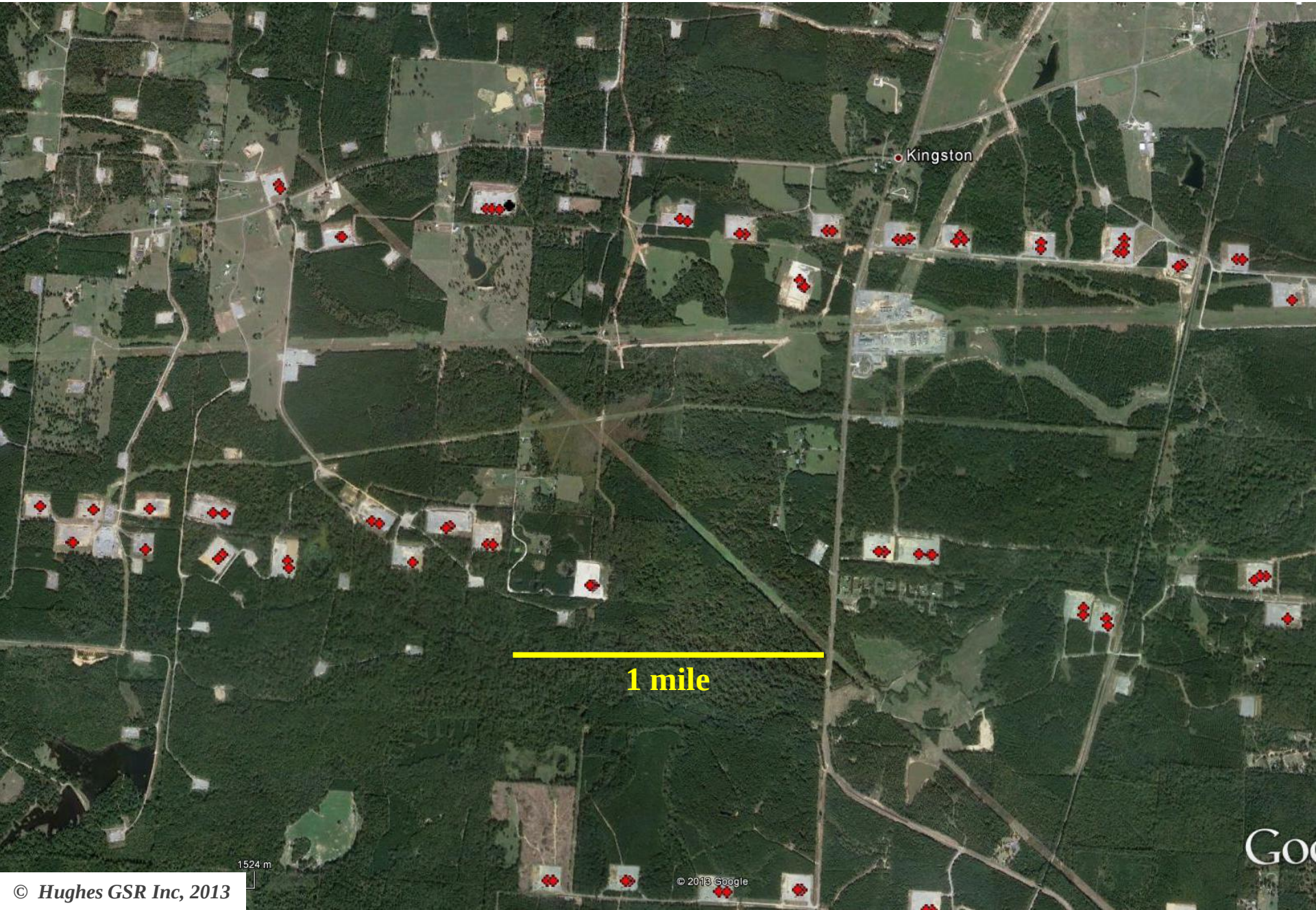
(data from DrillingInfo/HPDI, March, 2013)

Haynesville Average Production per Well Comparing Sweet Spot to Non-Sweet Spot Wells



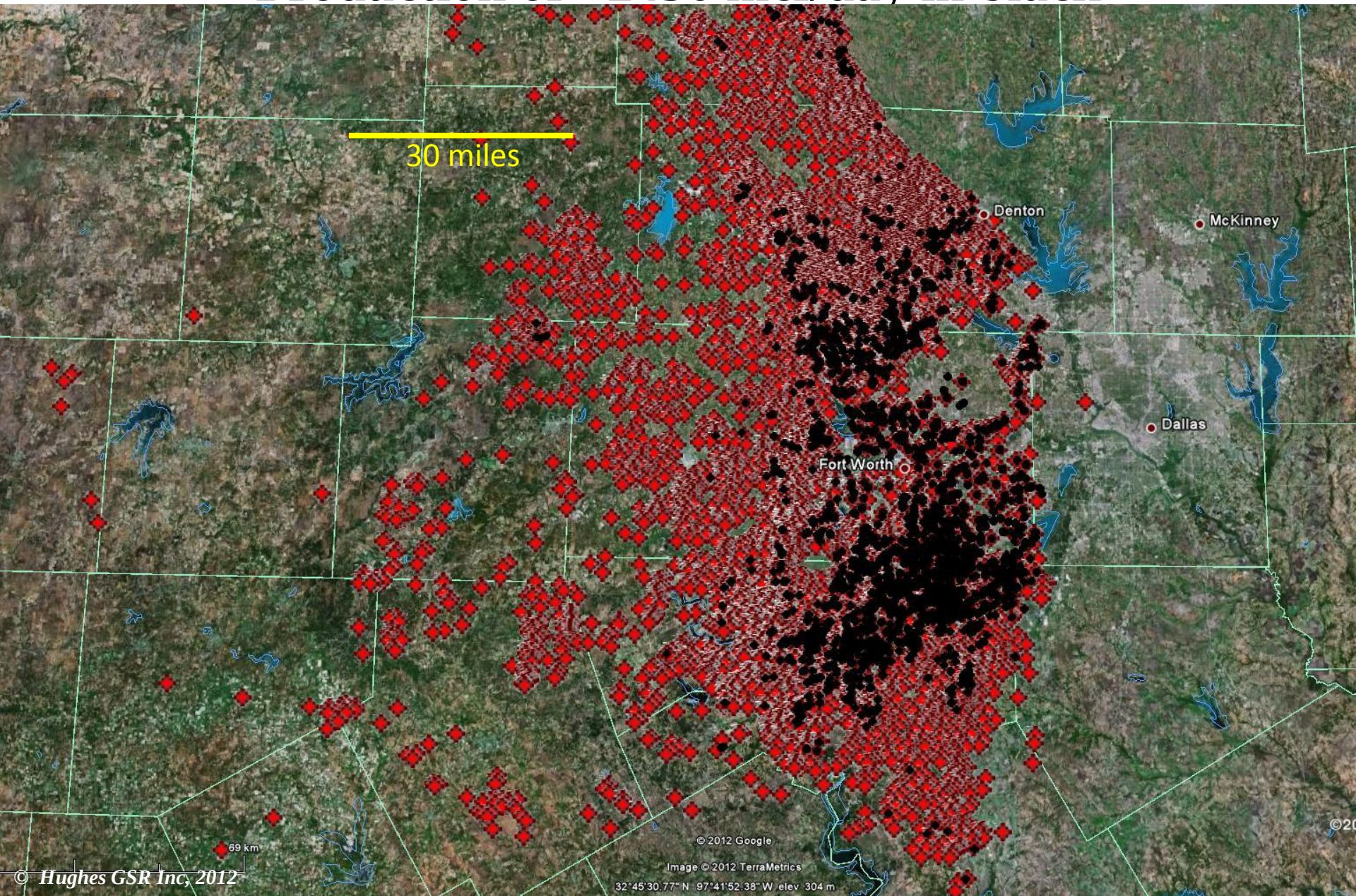
(data from DrillingInfo/HPDI, May, 2013)

Haynesville Sweet Spot Well Footprint



Haynesville Sweet Spot Well Footprint

Barnett Well Quality - Top 20% with Highest One Month Production of >2436 mcf/day in black



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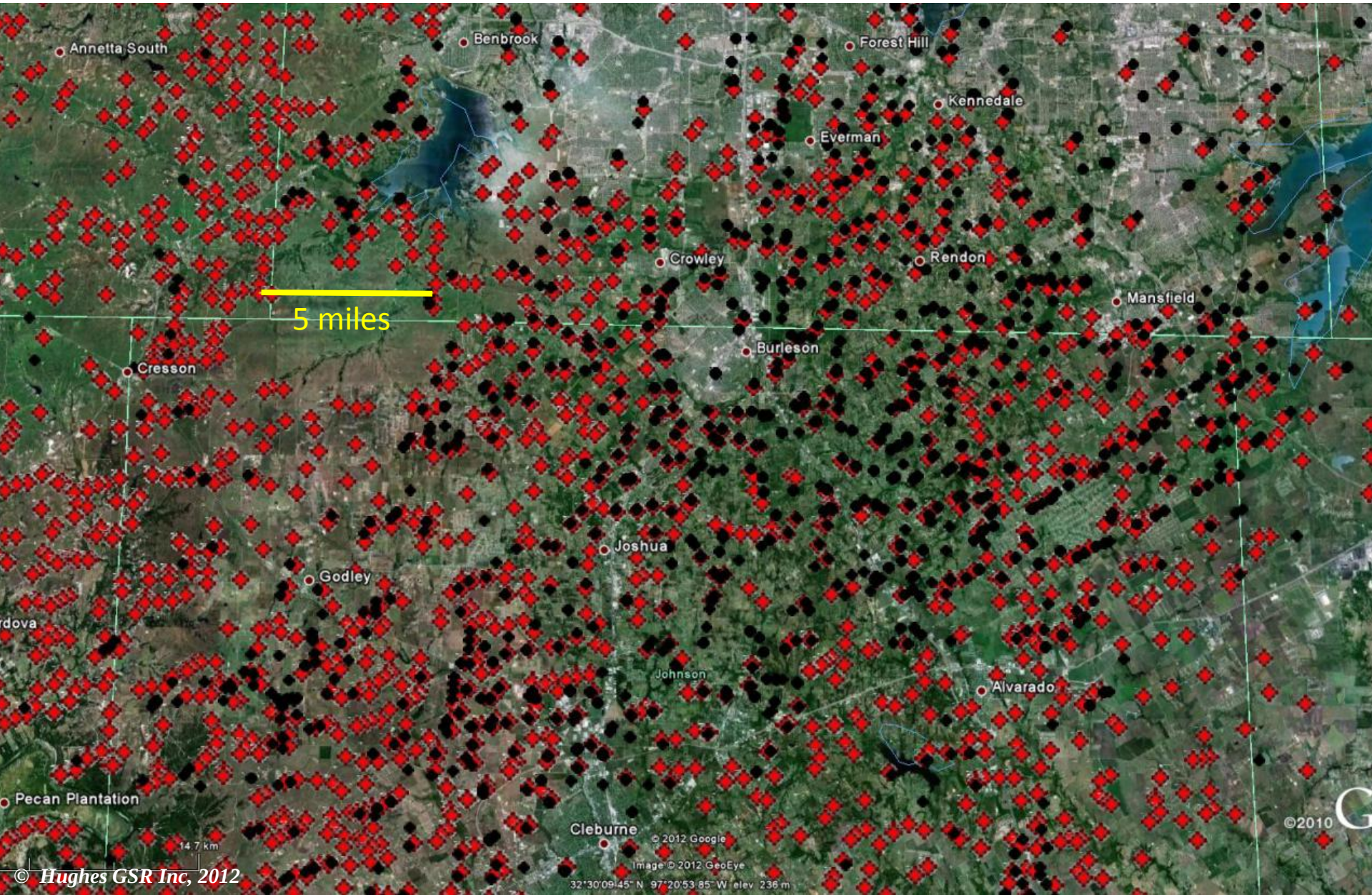
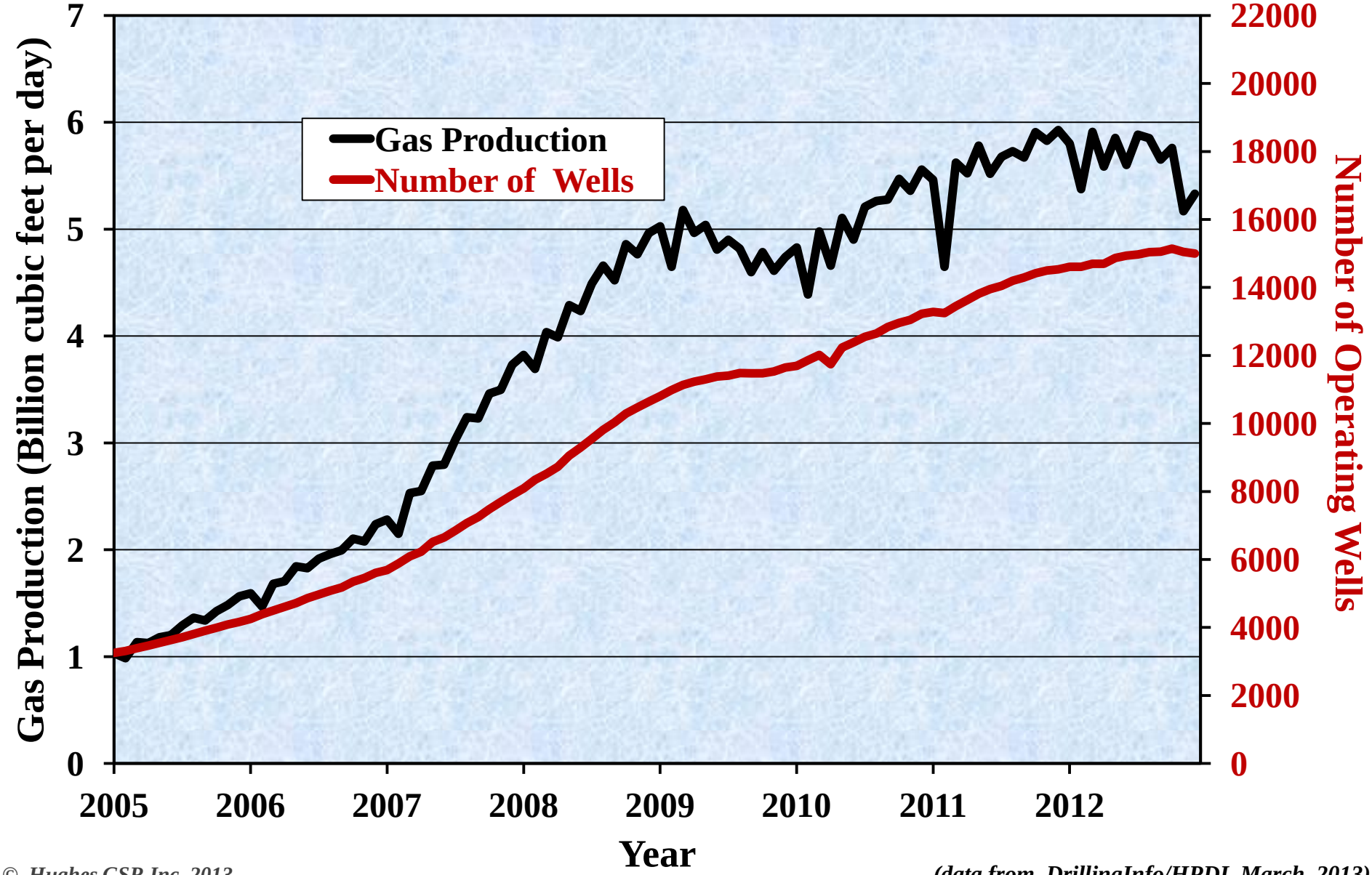


Barnett Gas Production and Number of Operating Wells, 2007-2012



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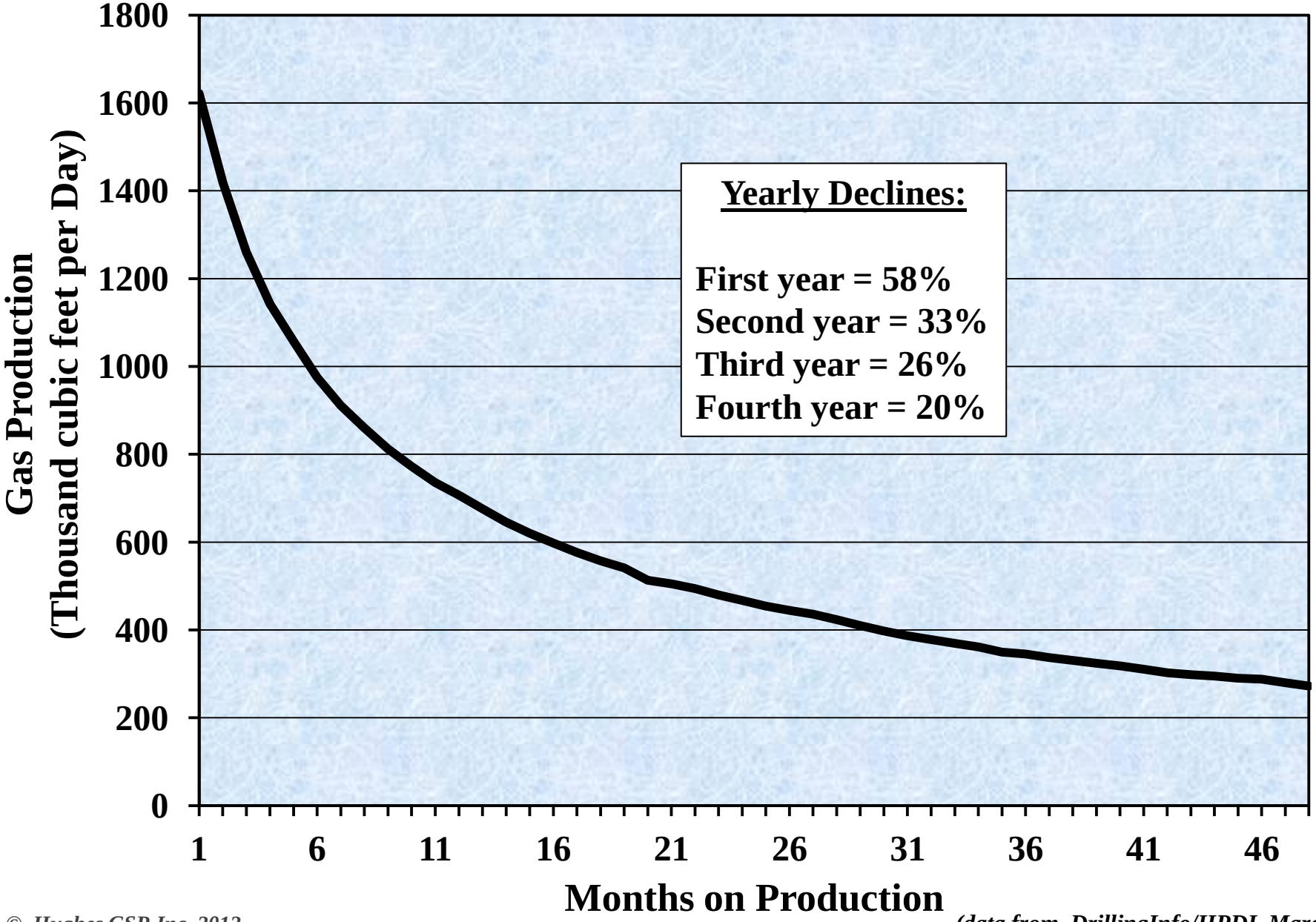
Barnett Type Gas Well Decline Curve



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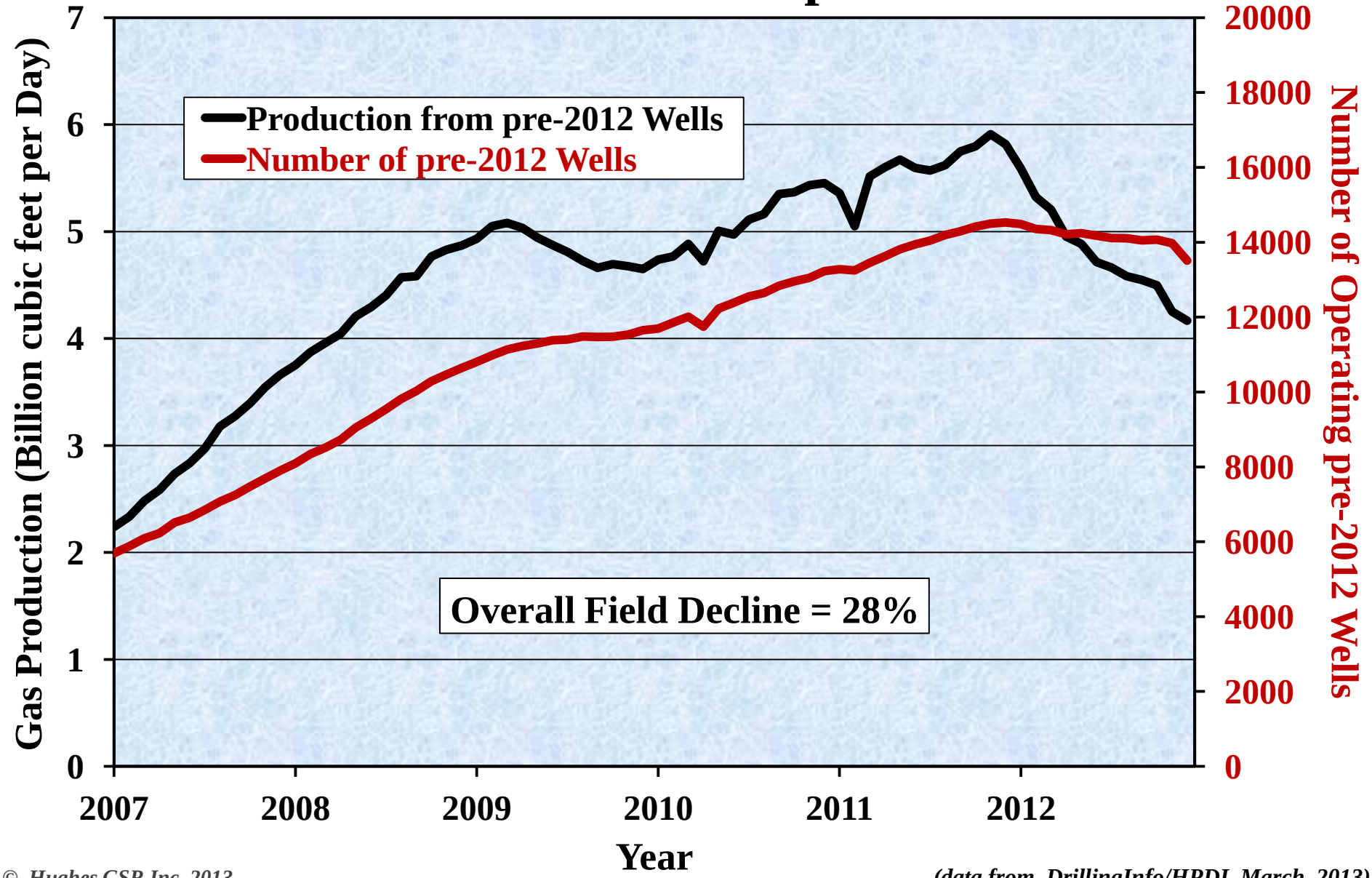
Overall Field Decline for Barnett Gas Production based on Production Decline from pre-2012 Wells



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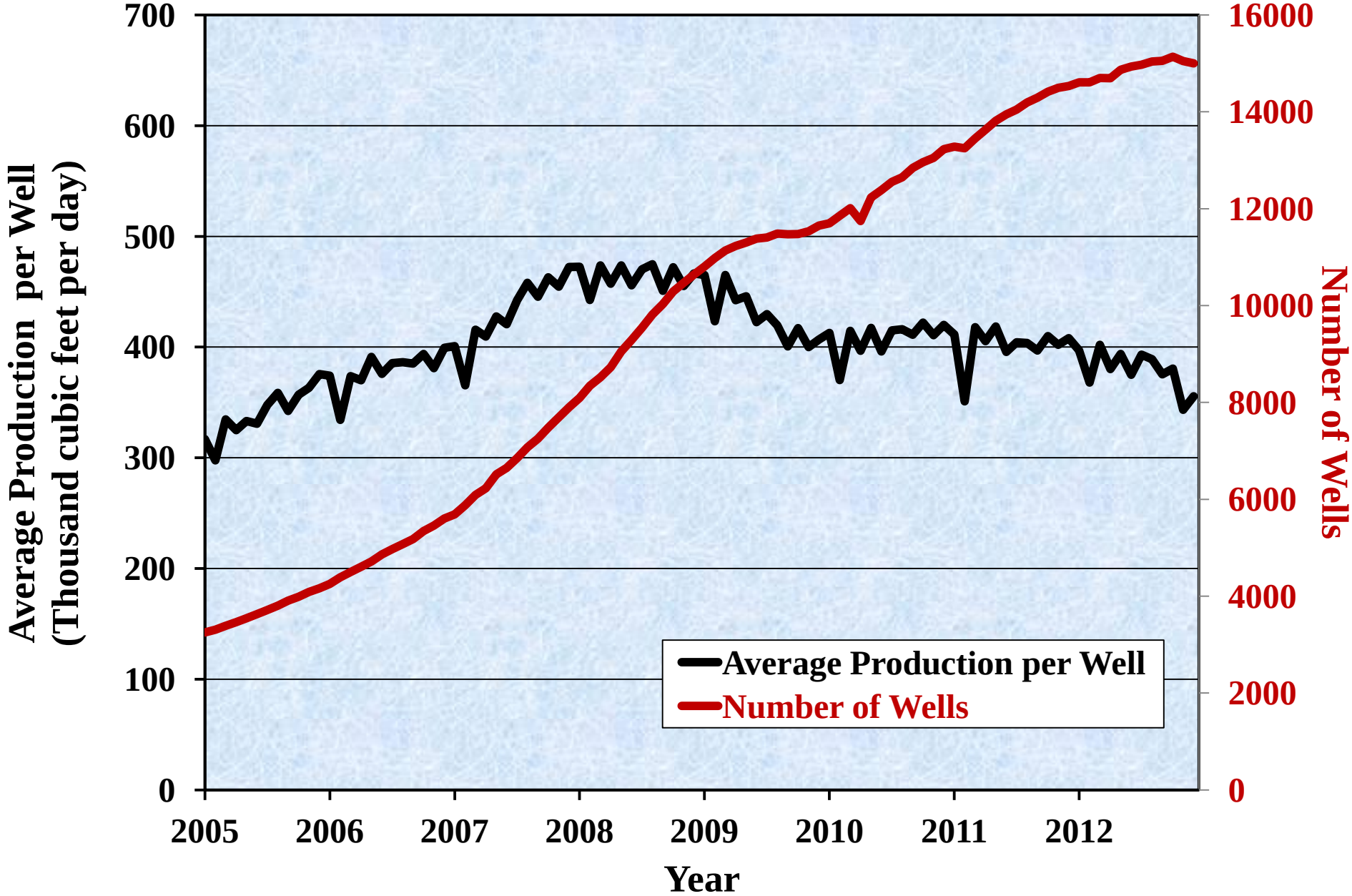
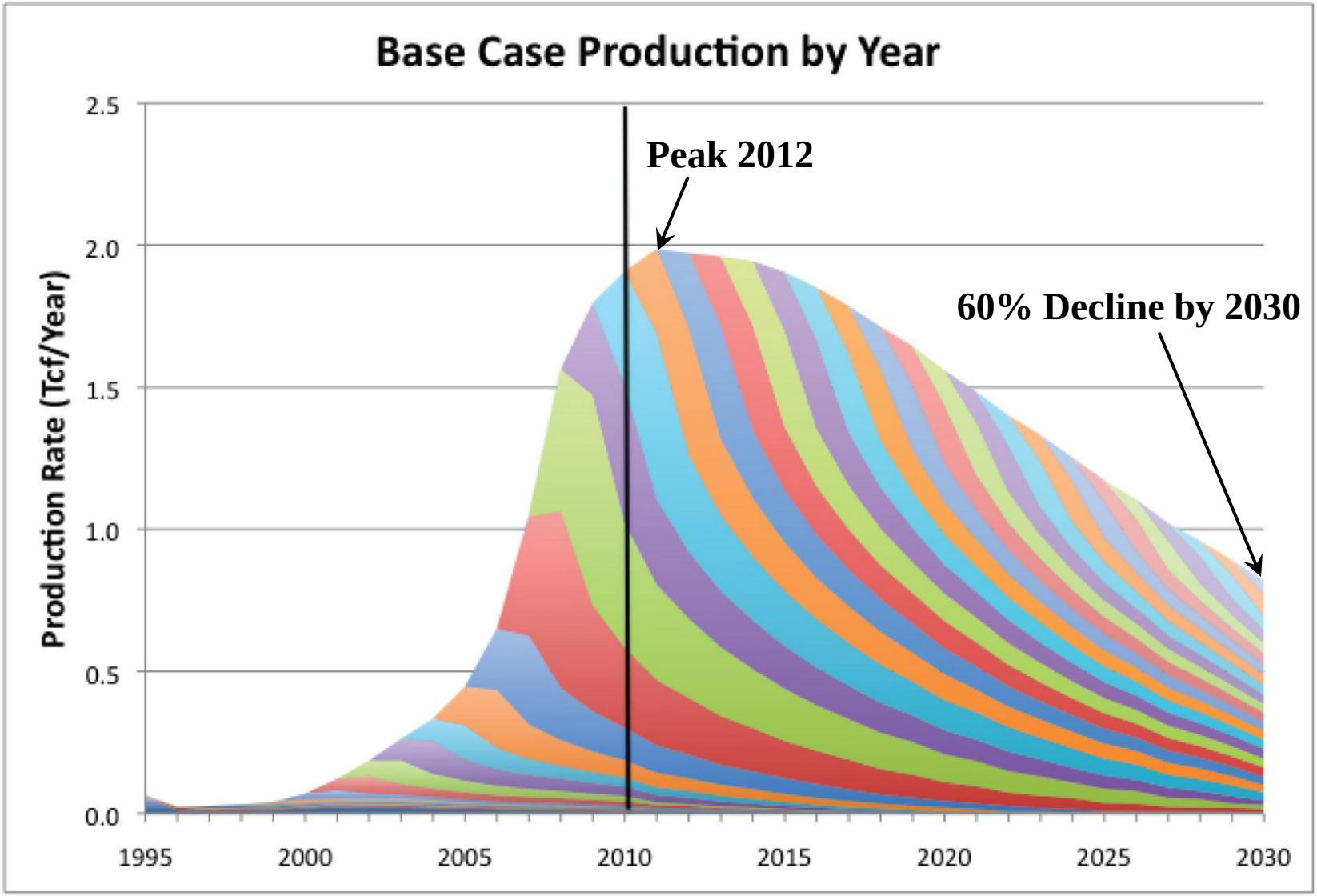
Barnett Average Production per Well



(data from DrillingInfo/HPDI, March, 2013)

University of Texas Barnett Study Heralded as a Good News Story of Long Term Growth by Wall Street Journal (Feb 2013)

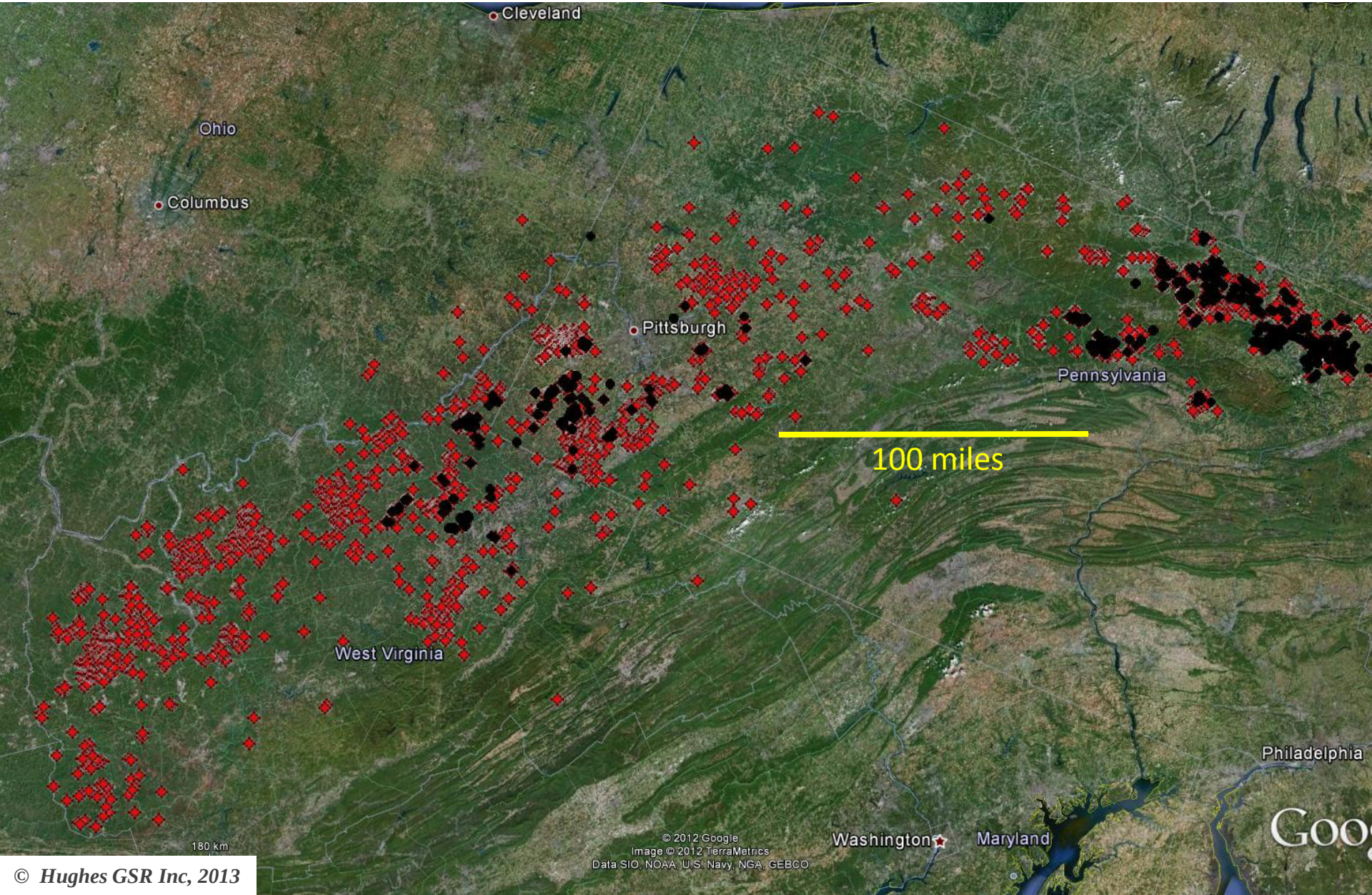


Bureau of Economic Geology

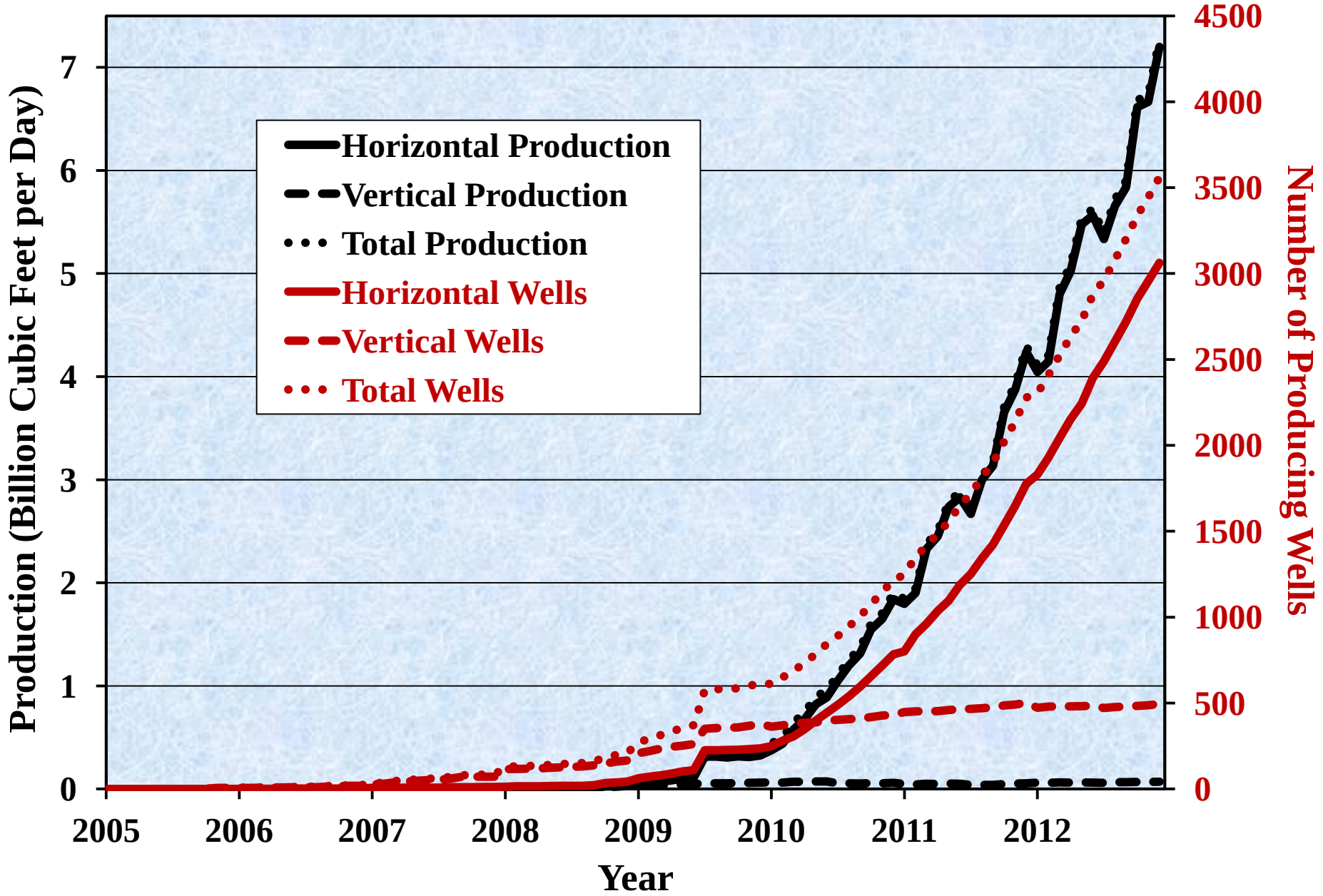
Source: Bureau of Economic Geology/Univ. of Texas at Austin

QAe1590

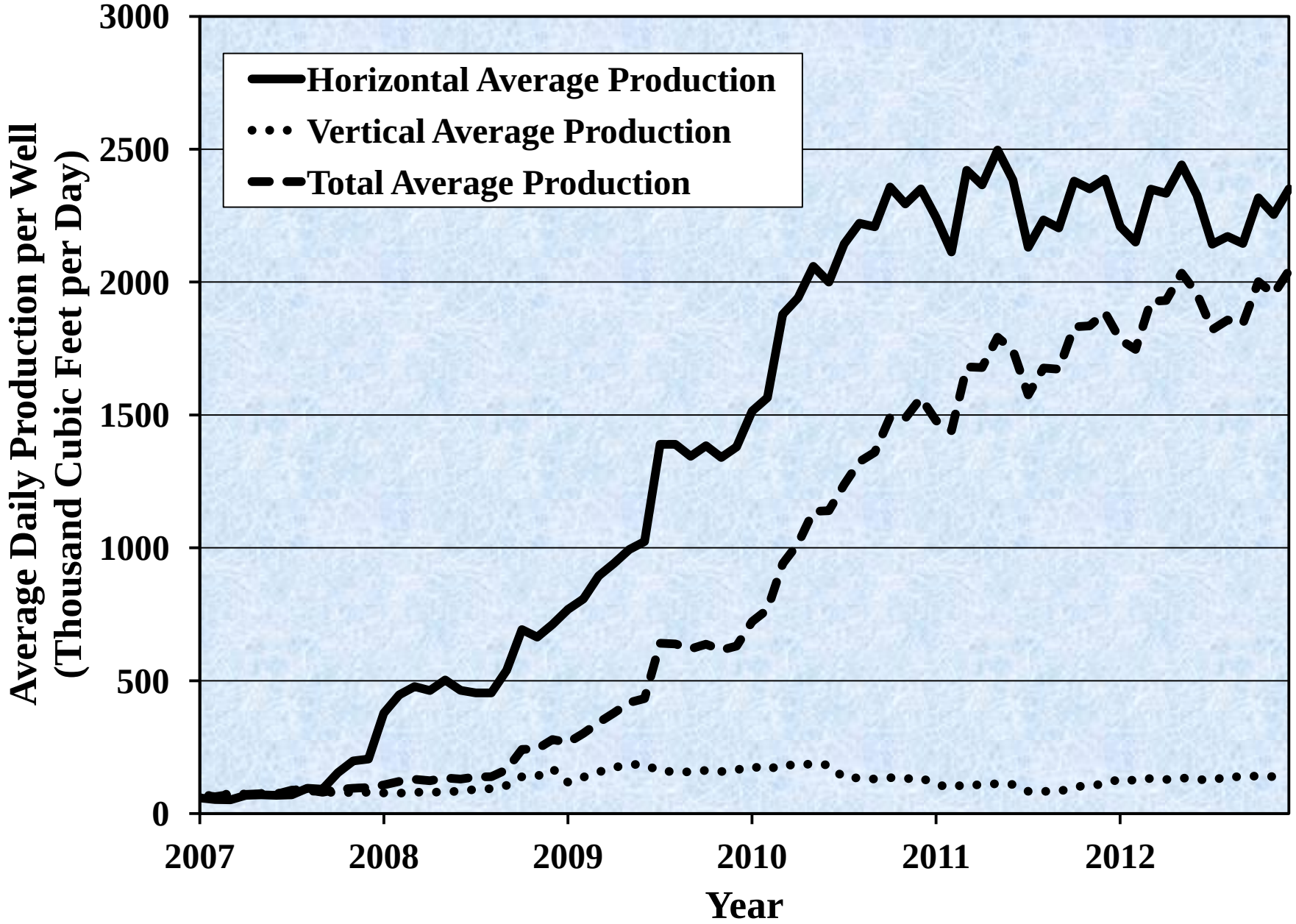
Marcellus Well Quality - Top 20% with Highest One Month Production of >3603 mcf/day in black



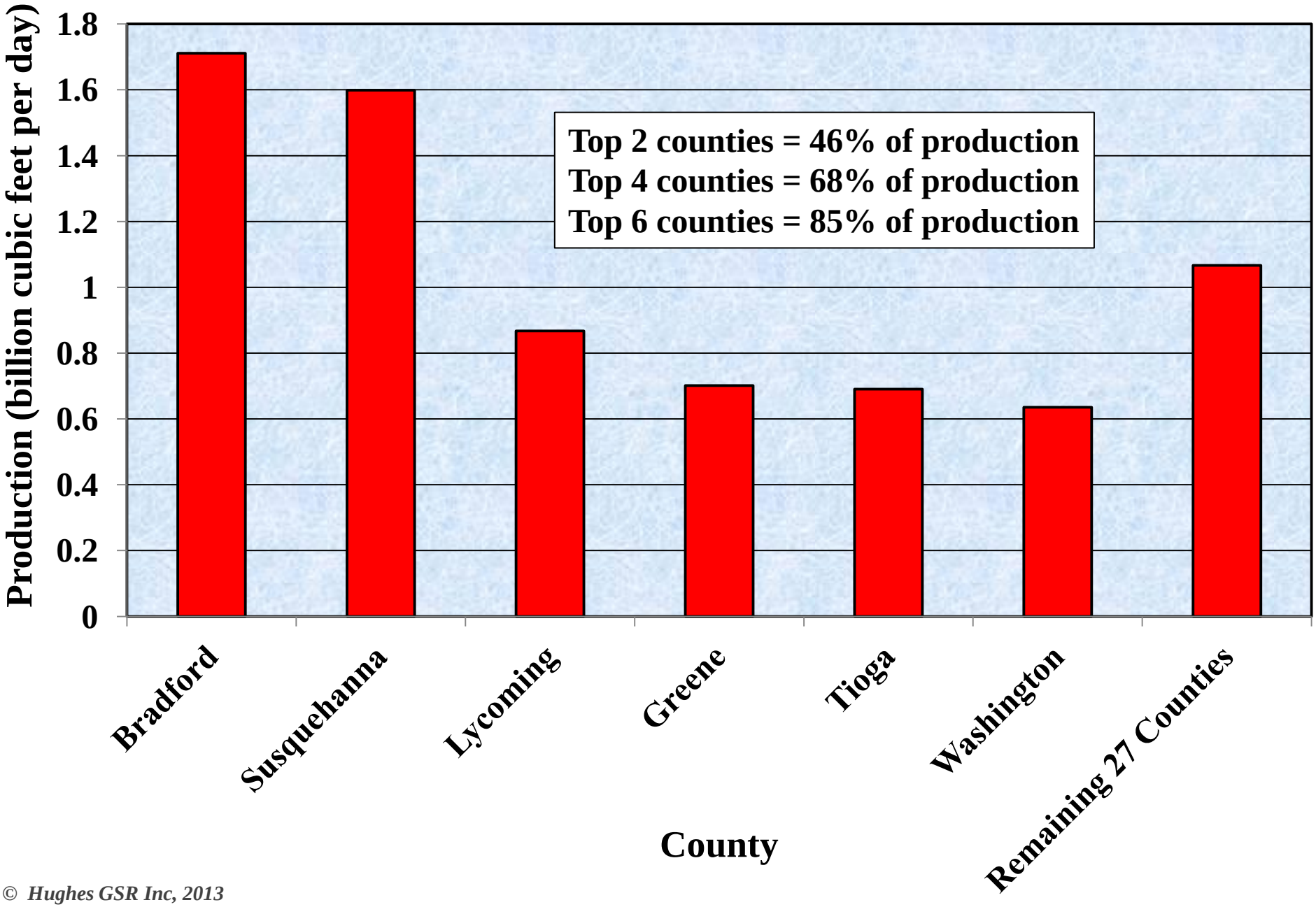
Pennsylvania Marcellus Production vs Well Type



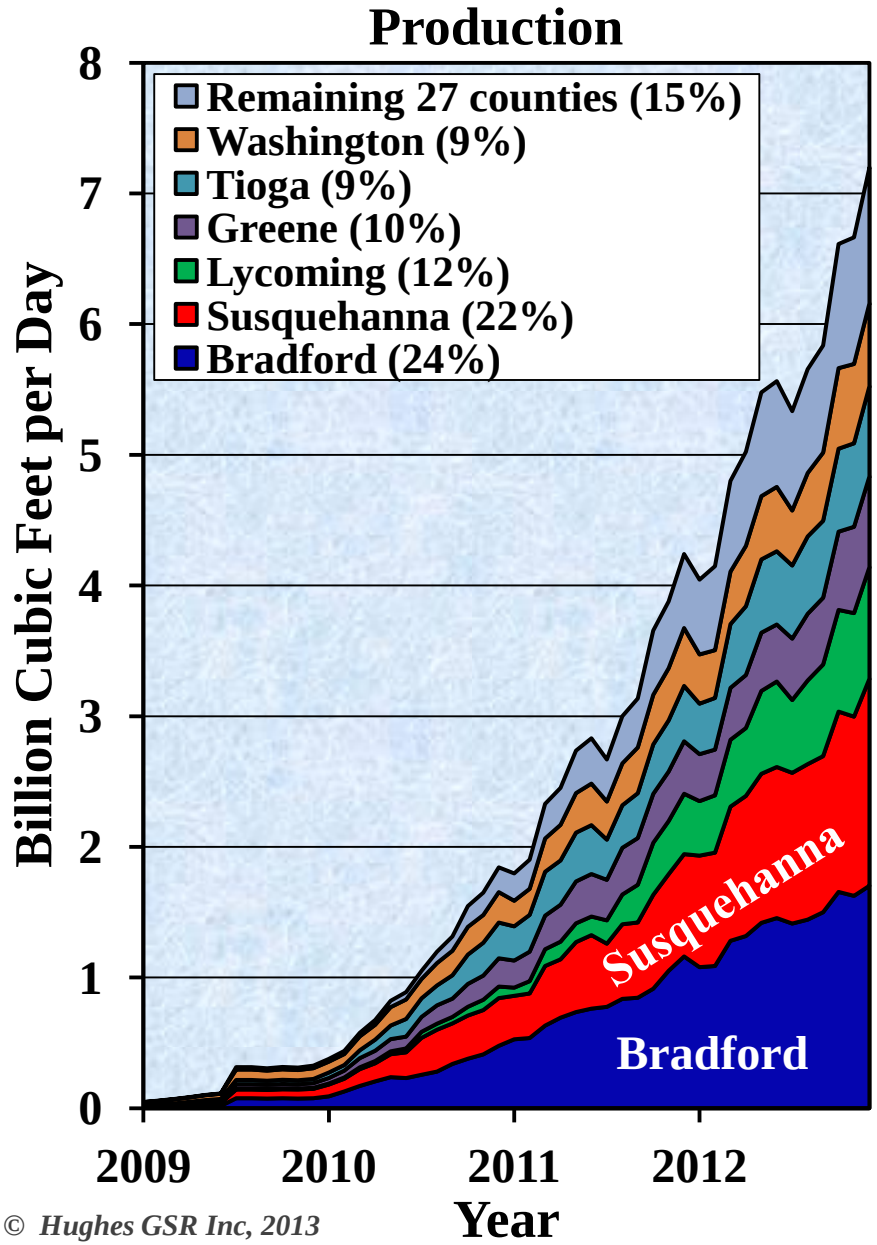
Pennsylvania Marcellus Daily Well Production by Well Type

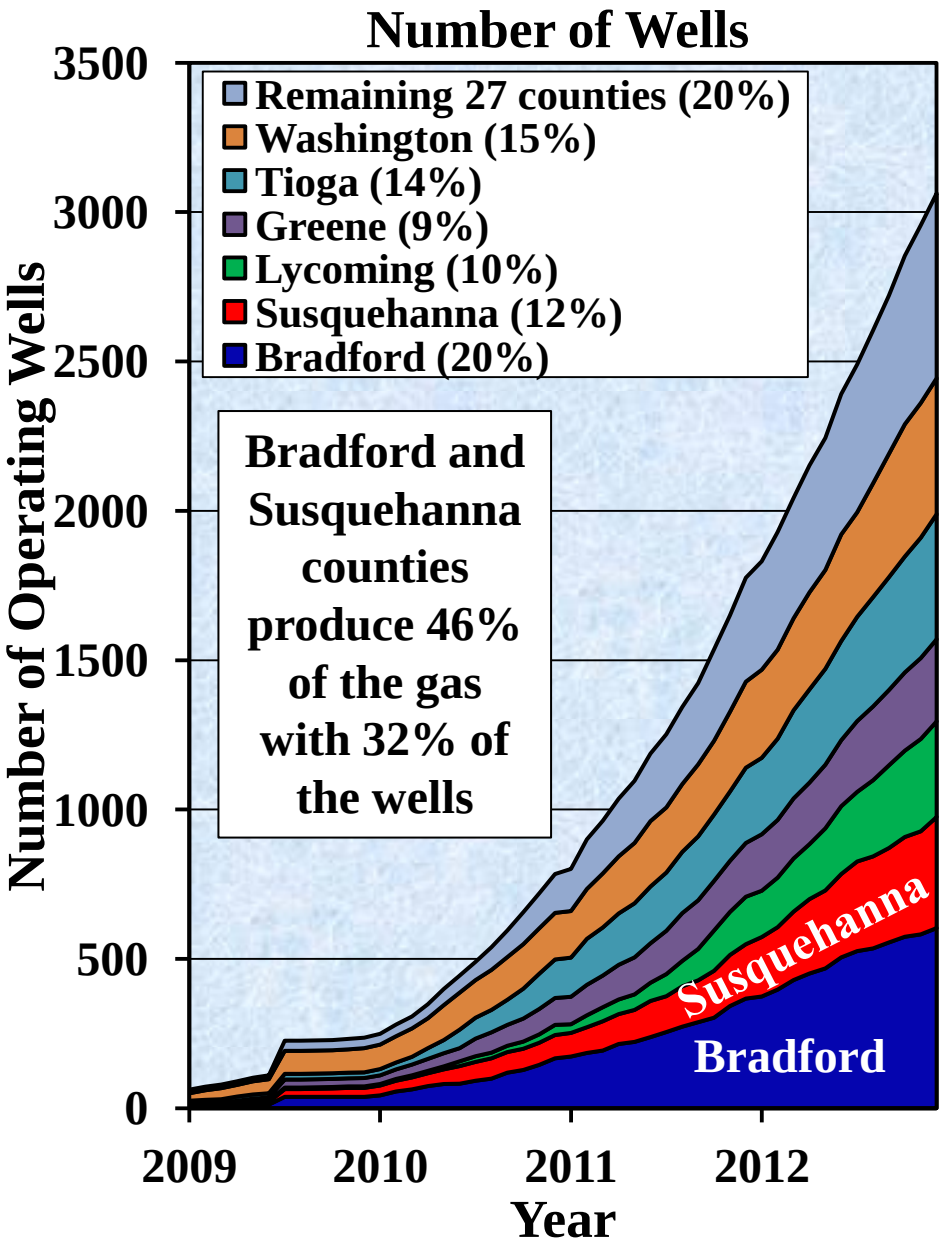


Pennsylvania Marcellus Production By County

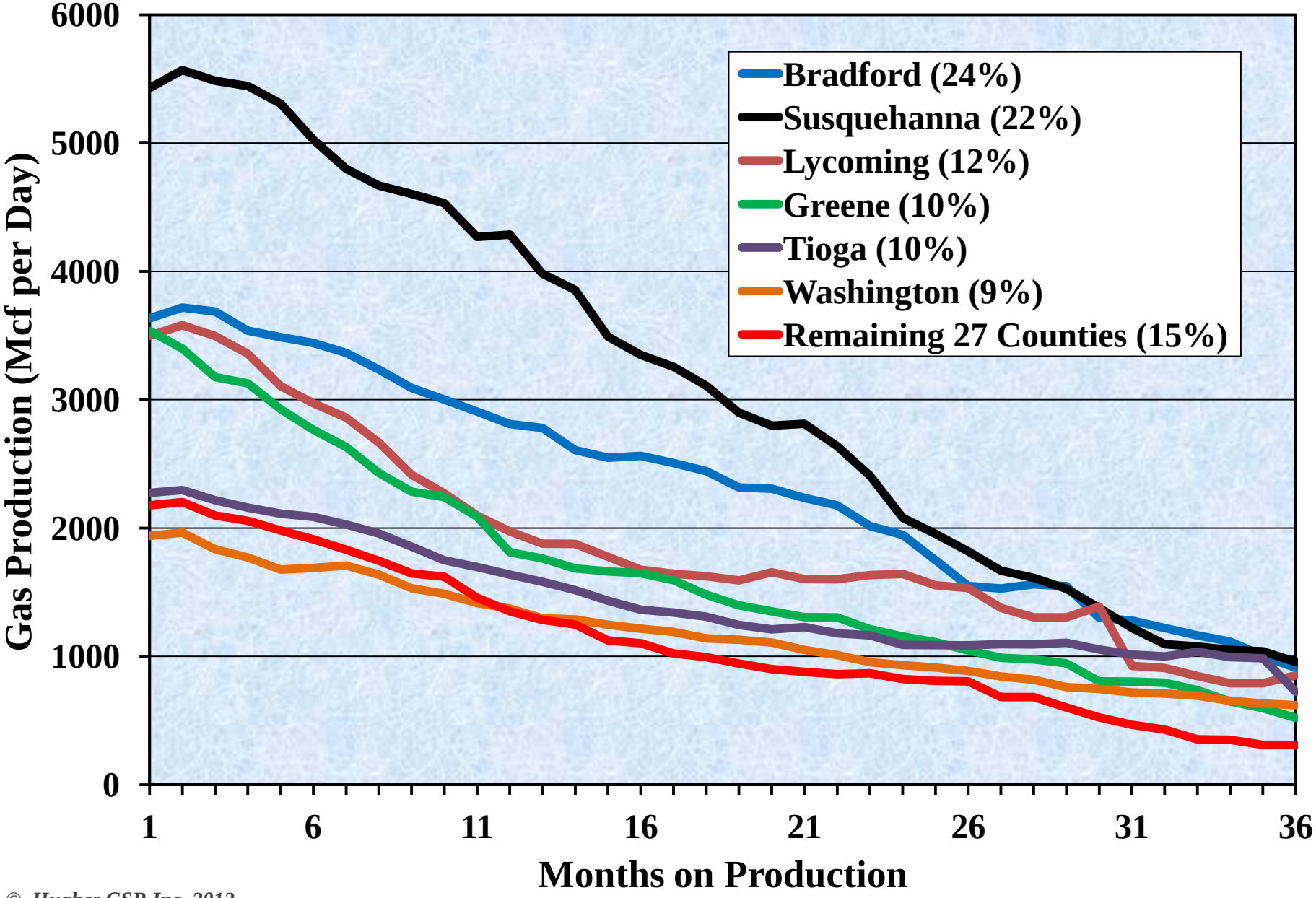


Pennsylvania Marcellus Production and Number of Horizontal Wells by County

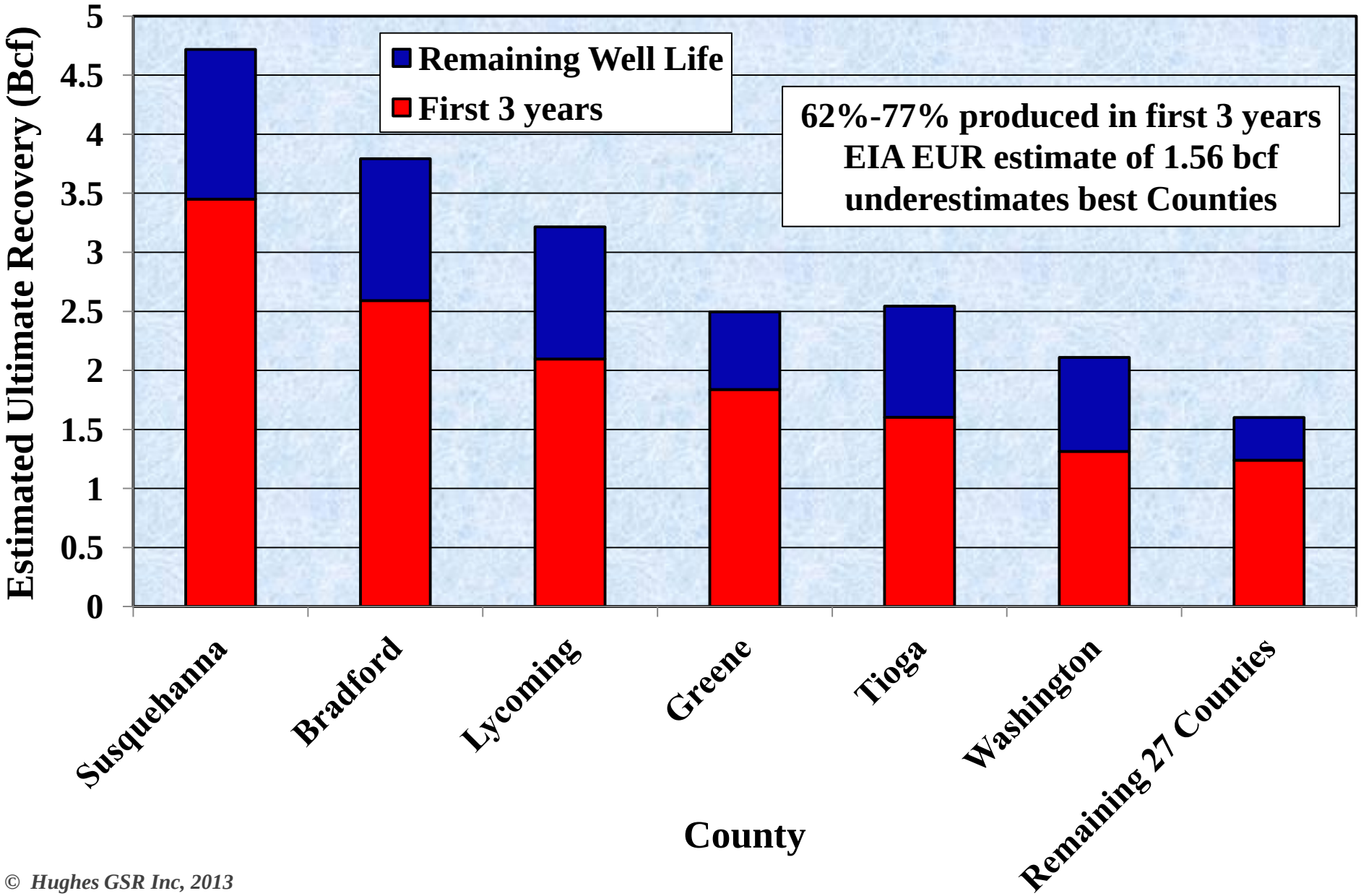




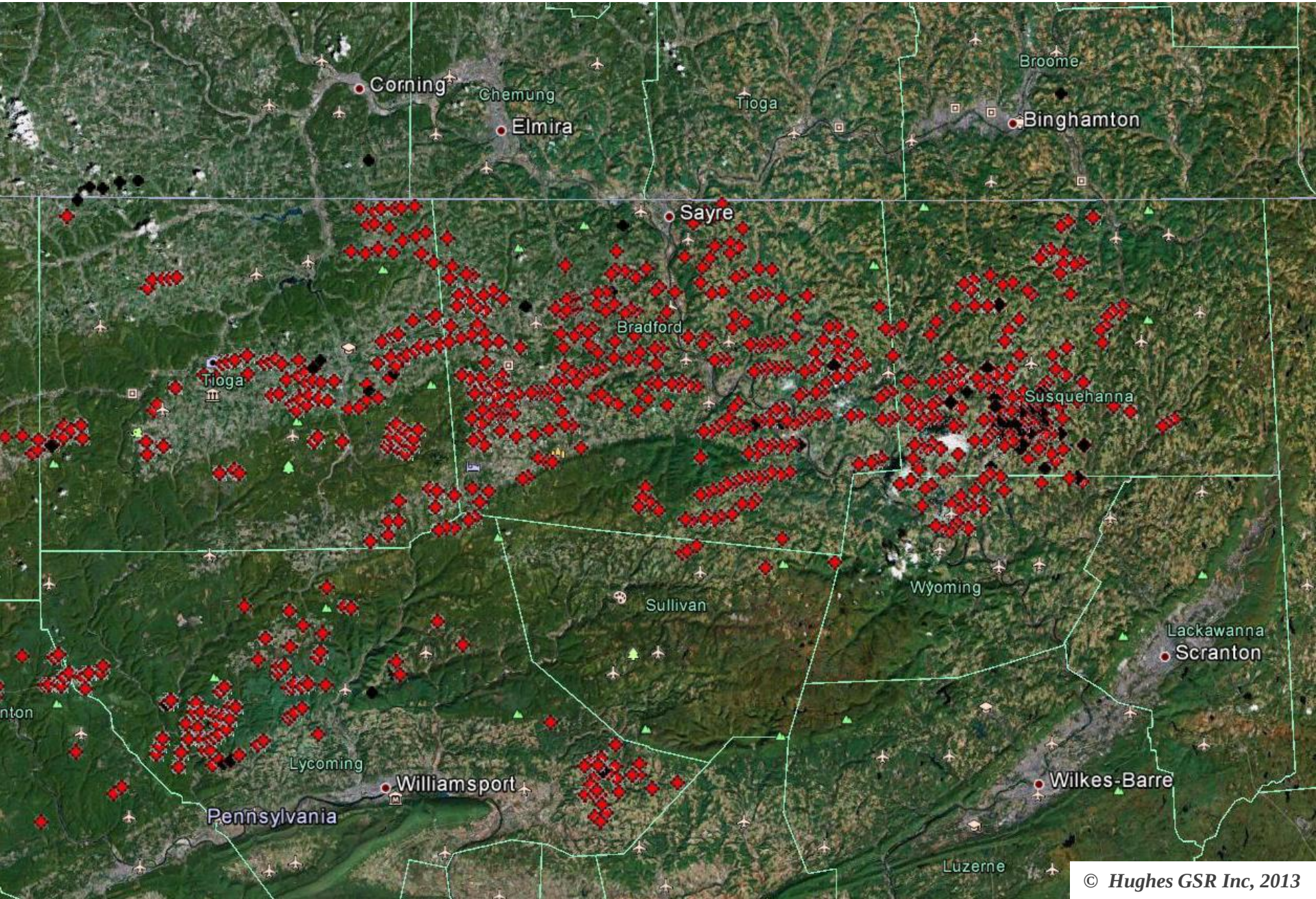
Type Decline Curves for Marcellus Horizontal Wells by County



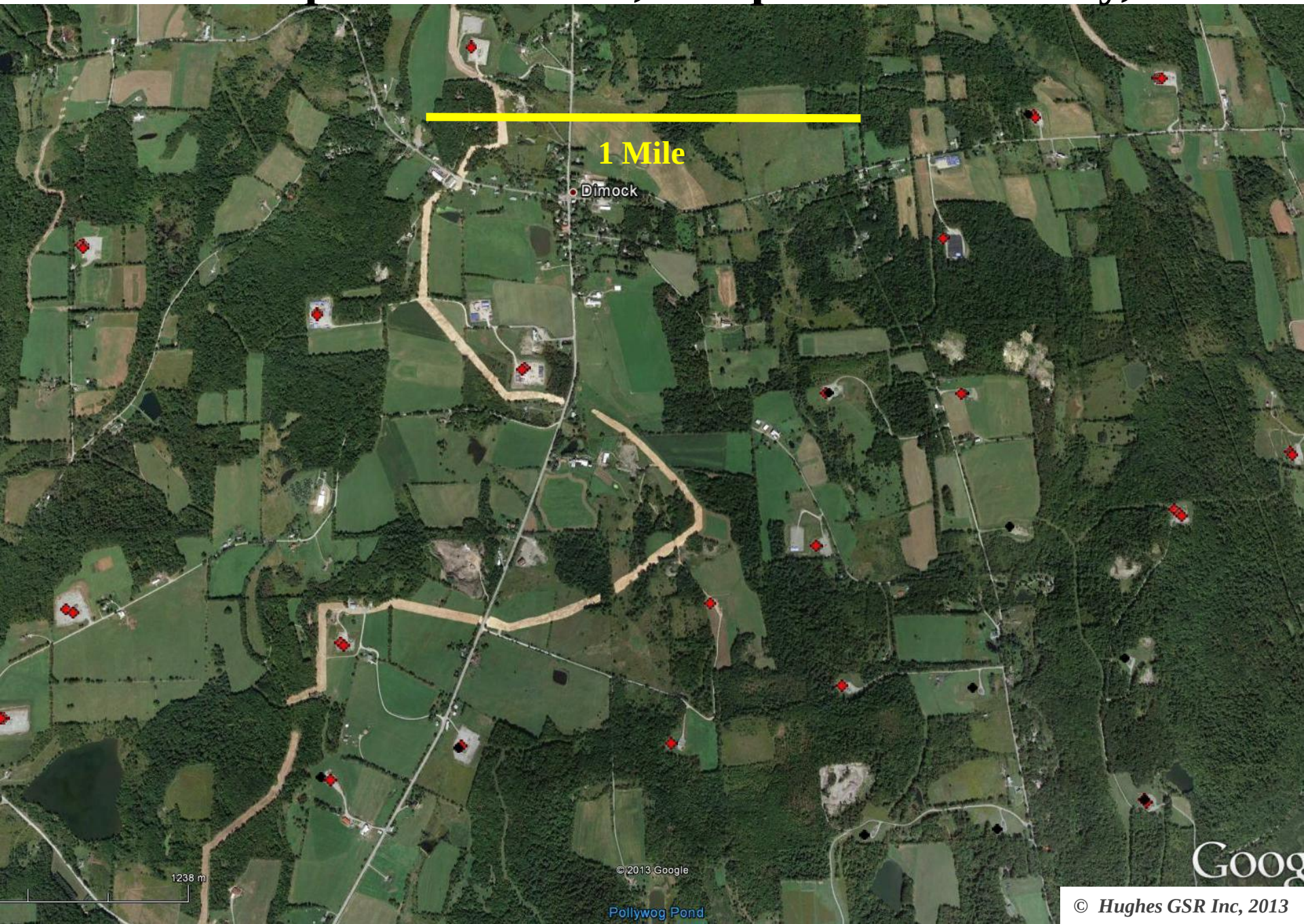
Estimated Ultimate Recovery for Pennsylvania Marcellus Horizontal Wells By County



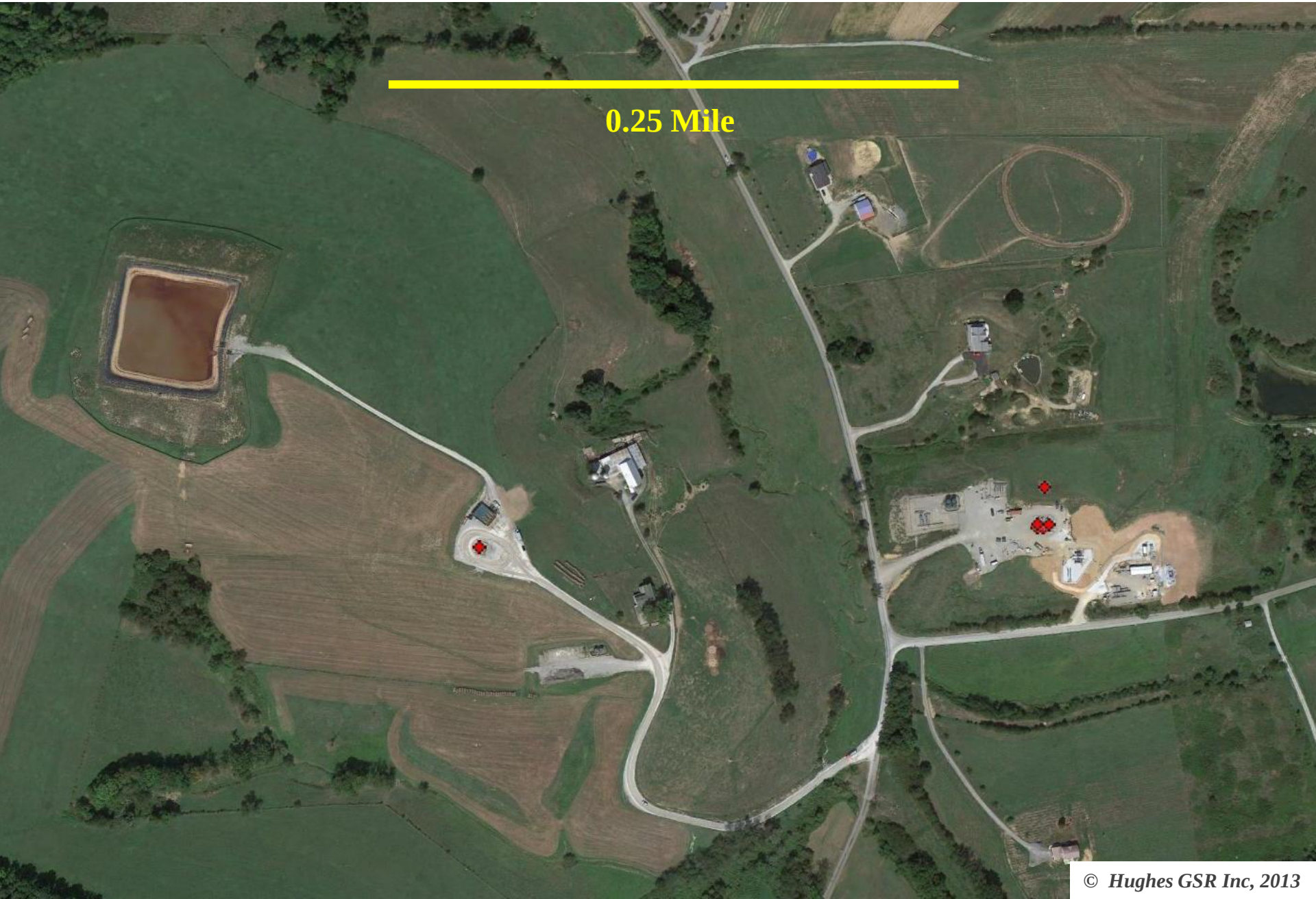
Top Tier Counties (Red=Horizontal; Black=Vertical)



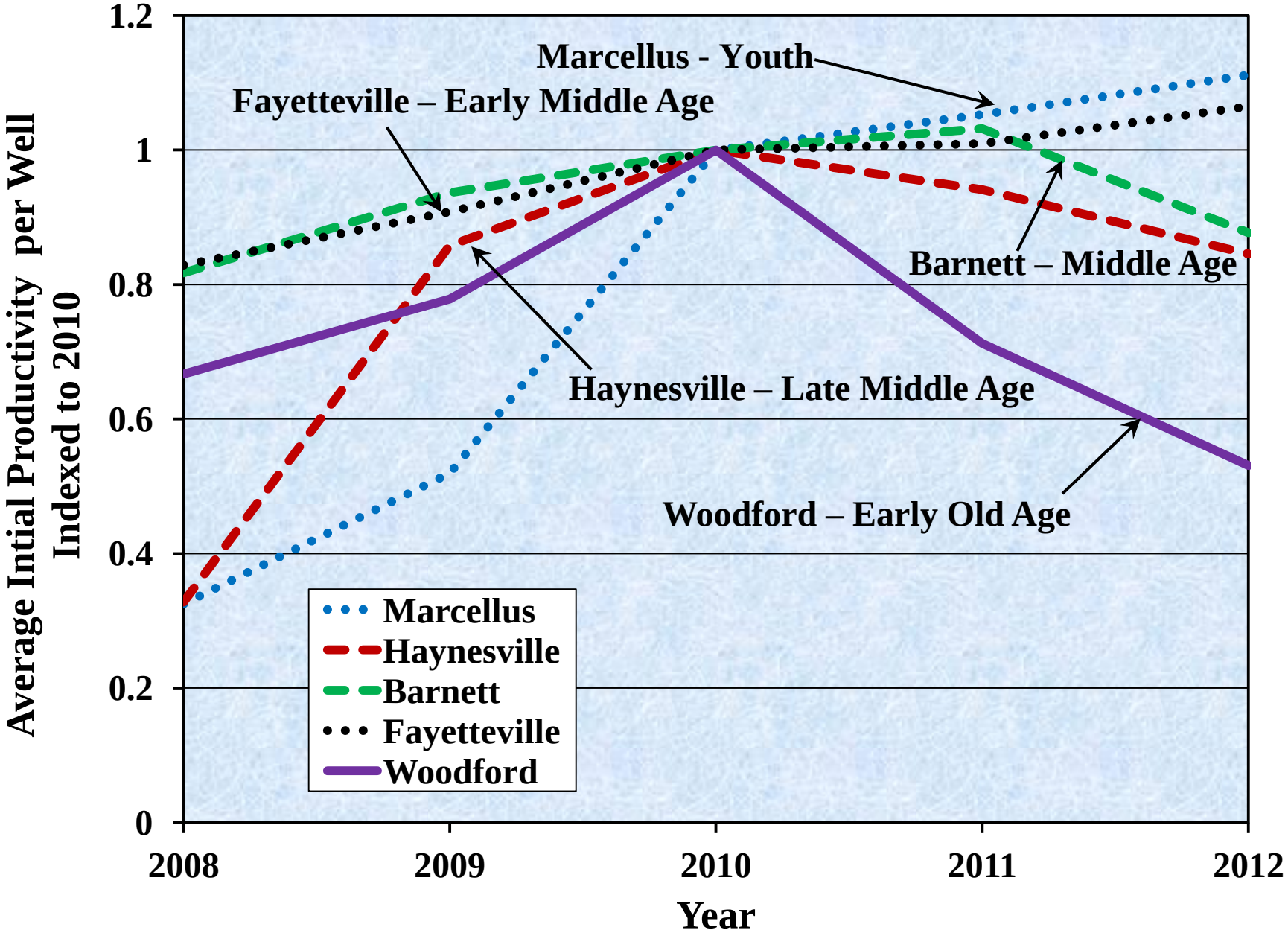
Well Footprint – Dimock, Susquehanna County, PA



Well Footprint – Washington County, Pennsylvania



Horizontal Well Quality Trends – Top Five Shale Gas Plays



(data from DrillingInfo/HPDI, March, 2013)

Prognosis for Future Production based on Latest Rig Count

Field	Rank	Number of Wells needed annually to offset decline	Wells Added for most recent Year	October 2012 Rig Count	Prognosis
Haynesville	1	774	810	20	Decline
Barnett	2	1507	1112	42	Decline
Marcellus	3	561	1244	110	Growth
Fayetteville	4	707	679	15	Decline
Eagle Ford	5	945	1983	274	Growth
Woodford	6	222	170	61	Decline
Granite Wash	7	239	205	N/A	Decline
Bakken	8	699	1500	186	Growth
Niobrara	9	1111	1178	~60	Flat

Annual Capex Required to Offset Overall Annual Decline by Shale Play

Field	Rank	Number of Wells needed annually to offset decline	Approximate Well Cost (million $US)	Annual Well Cost to Offset Decline (million $US)
Haynesville	1	774	9.0	6966
Barnett	2	1507	3.5	5275
Marcellus	3	561	4.5	2525
Fayetteville	4	707	2.8	1980
Eagle Ford	5	945	8.0	7558
Woodford	6	222	8.0	1776
Granite Wash	7	239	6.0	1434
Bakken	8	699	10.0	6990
Niobrara	9	1111	4.0	4444
Antrim	10	~400	0.5	200
Bossier	11	21	9.0	189
Bone Spring	12	206	3.7	762
Austin Chalk	13	127	7.0	889
Permian Delaware Midland	14	122	6.9	842
Total		**7641**		**41829**

(well cost data from various sources and is approximate)

The Reality Check

"We are all losing our shirts today." **Rex Tillerson [CEO of Exxon Mobil] said** ***"We're making no money. It's all in the red."***
(Wall Street Journal, June, 2012)

2012 Impairment Charges on U.S. Shale Assets

- Chesapeake - $2.02 Billion

- BP - $2.11 Billion

- BHP - $2.84 Billion

- BG Group - $1.3 Billion

And there is no such thing as a *FREE LUNCH*

There has been a great deal of pushback by many in the general public and in State and National governments to environmental issues surrounding hydraulic fracturing

- High levels of water consumption

- Methane contamination of groundwater

- Disposal of produced fracture fluid potentially contaminating groundwater and inducing earthquakes

-Industrial footprint – truck traffic, air emissions etc.

-Full cycle greenhouse gas emissions which may be worse than coal

The Shale "REVOLUTION"

- **Over-hyped in terms of long term supply especially at low forecast prices.**
- **High quality shale plays are not ubiquitous - *88% of shale gas production comes from 6 of 30 plays; 81% of tight oil production comes from 2 of 21 plays.***
- **High field decline rates require a drilling treadmill to maintain production – *30-50% of production must be replaced each year with more drilling.***
- **The drilling treadmill will accelerate as sweet spots are drilled off and well quality declines as drilling moves into more marginal areas.**
- **Collateral environmental impacts associated with fracking have already, and will continue to create public opposition to unfettered access to drill sites which are mandatory to maintain supply.**

Implications

- The "Shale Revolution" has been a "game-changer" in that it has temporarily reversed a terminal decline in supplies from conventional sources. Long term sustainability is highly questionable and environmental impacts are a major concern.
- Almost all eggs are in the shale basket as a hope in meeting U.S. energy supply growth projections from oil and gas.
- US "Energy Independence" with the forecast energy trajectory is highly unlikely, barring a radical reduction in consumption.
- Replicating the "Shale Revolution", to the extent it exists, will take much longer in Europe, if ever. There is no reason to expect that the geology will be much different – the greatest potential will lie in a few plays and parts thereof. Higher population densities will make surface access for the large number of drilling locations required much more difficult. Due to high population densities the collateral environmental impacts of fracking are likely to be even more apparent – and opposed – than they are in the U.S.