# Fracking for Tight Oil and Shale Gas in the U.S.

## Terminology

1. **Crude Oil**: Liquid petroleum extracted from the Earth (barrels, bbl)
2. **Natural Gas**: Mixture of hydrocarbon and non-hydrocarbon gases extracted from the Earth ($ft^3$, cf)
3. **Tight Oil**: "Also referred to as shale oil. Oil contained in shale and associated clastic and carbonate rocks with very low permeabilities in the micro- to nano-darcy range. Typically produced using horizontal wells with multistage hydraulic fracture treatments." (darcy = unit of permeability)
4. **Shale Gas**: "Gas contained in shale with very low permeabilities in the micro- to nano-darcy range. Typically produced using horizontal wells with multistage hydraulic fracture treatments."
5. **Condensate**: Liquid hydrocarbon extracted with natural gas from the Earth (barrels, bbl) (gas-well oil)
6. **Casinghead:** Natural gas extracted with crude oil from the Earth ($ft^3$, cf) (oil-well gas)

## A Summary of J. David Hughes' Micro-Analyses

***Drilling Deeper: A Reality Check on U.S. Government Forecasts for a Lasting Tight Oil & Shale Gas Boom***

"Drilling Deeper reviews the twelve shale plays that account for 82% of the tight oil production and 88% of the shale gas production in the U.S. … It utilizes all available production data for the plays analyzed, and assesses historical production, well- and field-decline rates, available drilling locations, and well-quality trends for each play, as well as counties within plays. Projections of future production rates are then made based on forecast drilling rates (and, by implication, capital expenditures). … This report finds that tight oil production from major plays will peak before 2020 … Barring major new discoveries on the scale of the Bakken or Eagle Ford. … Shale gas production from the top seven plays will also likely peak before 2020. … Barring major new discoveries on the scale of the Marcellus … Over the short term, U.S. production of both shale gas and tight oil is projected to be robust—but a thorough review of production data from the major plays indicates that this will not be sustainable in the long term. These findings have clear implications for medium and long term supply, and hence current domestic and foreign policy discussions, which generally assume decades of U.S. oil and gas abundance."

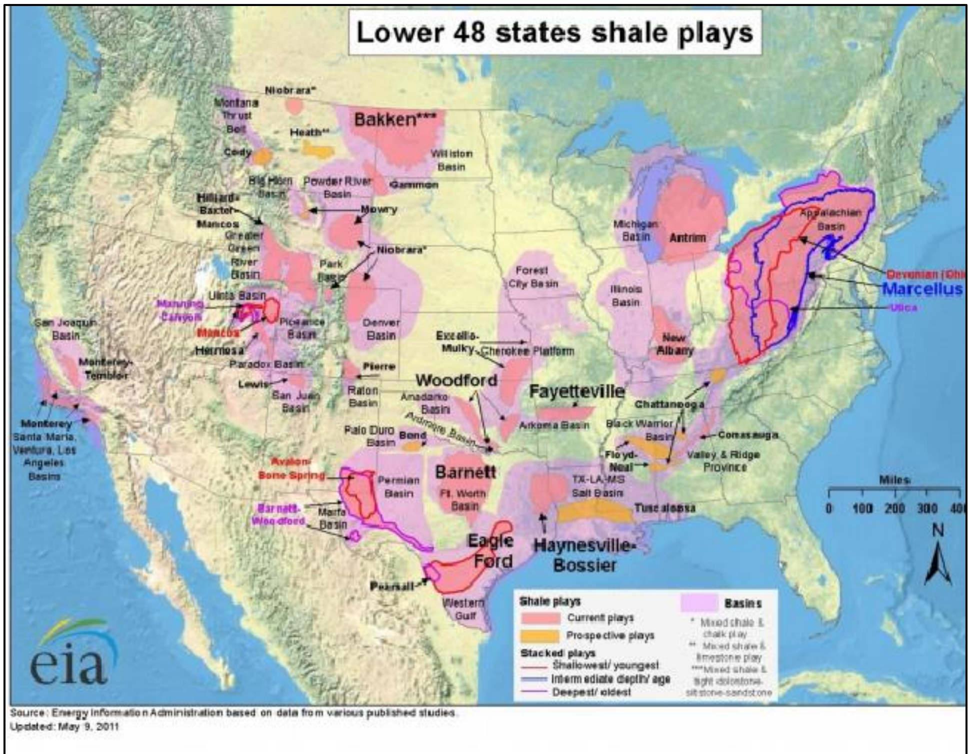



**Figure 2-6. Distribution of lower 48 states shale gas and oil plays.**[12]

The major fracking plays are:

- Tight Oil
  - Bakken in North Dakota and Montana
  - Eagle Ford in Texas
- Shale Oil
  - Haynesville in Louisiana and Texas
  - Marcellus in Pennsylvania and West Virginia

## Tight Oil Fracking

"Based on production history, drilling locations, and declining well quality, this report found that 98% of the [EIA](#)'s projected production from these seven plays has a "high" or "very high" optimism bias.":

| Play | Average 3-Year Well Decline Rate |
|---|---|
| Bakken | 85% |
| Eagle Ford | 79% |
| Spraberry | 60% |
| Wolfcamp | 81% |
| Bone Spring | 91% |
| Austin Chalk | 85% |
| Niobrara | 90% |

The seven major tight-oil plays also involve extraction of natural gas:

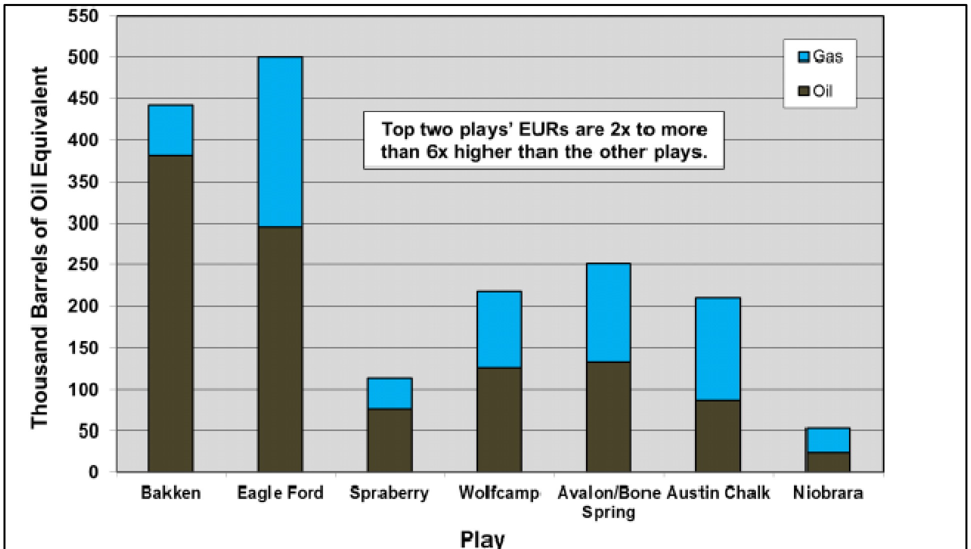



**Figure 1-4. Estimated ultimate recovery (EUR) of oil and gas per well of reviewed plays, on a "barrels of oil equivalent" basis.[8]**

The Bakken's and Eagle Ford's EURs per well are two to more than six times the EURs per well of the other five plays. If only horizontal wells are considered, the Bakken and Eagle Ford EURs per well are 39% to 141% higher than those of the other five plays (see discussion in Section 2).

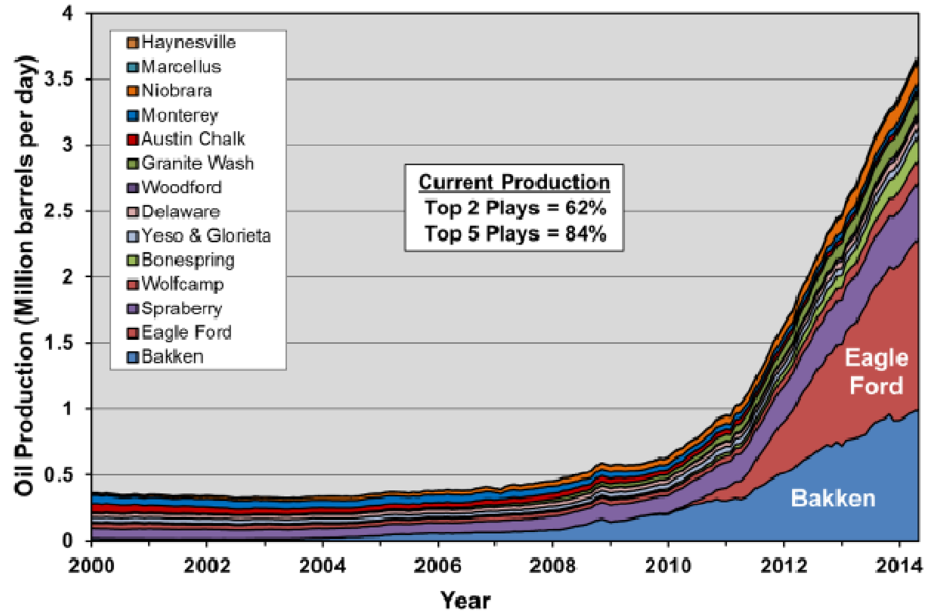



**Figure 2-7. U.S. tight oil production by play, 2000 through May 2014.**[13]

The Permian Basin, which is made up of several plays (the largest of which are noted), is the third largest projected source of tight oil.

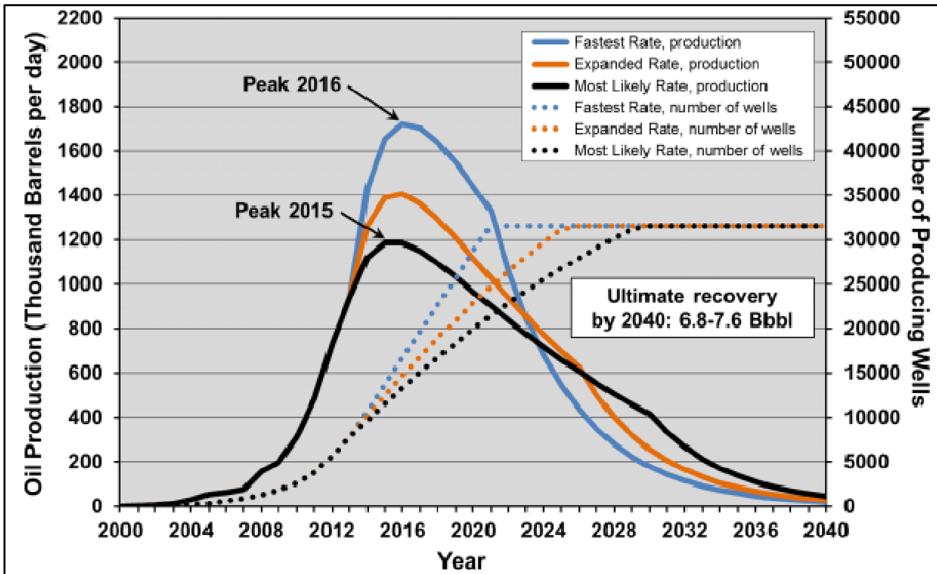



**Figure 2-26. Three drilling rate scenarios of Bakken tight oil production, in the "Realistic Case" (80% of the remaining play area is drillable at three wells per square mile).**[48]

"Most Likely Rate" scenario: drilling continues at 2,000 wells/year, declining to 1,000 wells/year;
"Expanded Rate" scenario: drilling increases to 2,500 wells/year, declining to 1,500 wells/year;
"Fastest Rate" scenario: drilling increases to 3,000 wells/year, holding constant.

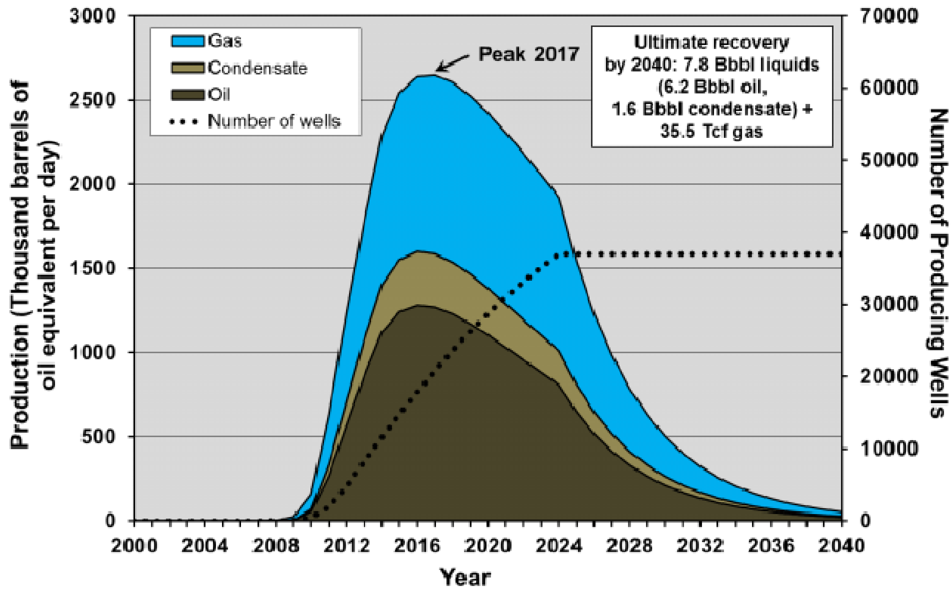



**Figure 2-52. "Most Likely Rate" scenario of Eagle Ford production for oil, condensate and gas in the "Realistic Case" (80% of the remaining area is drillable at six wells per square mile).[85]**

In this "Most Likely Rate" scenario, drilling continues at 3,550 wells/year, declining to 2,000 wells/year.

## Shale Gas Fracking

| Play | Average 3-Year Well Decline Rate | Average First-Year Field Decline Rate |
|---|---|---|
| Barnett | 75% | 23% |
| Haynesville | 88% | 49% |
| Fayetteville | 79% | 34% |
| Woodford | 74% | 34% |
| Marcellus | 74-82% | 32% |
| Eagle Ford | 80% | 47% |
| Bakken | 81% | 41% |

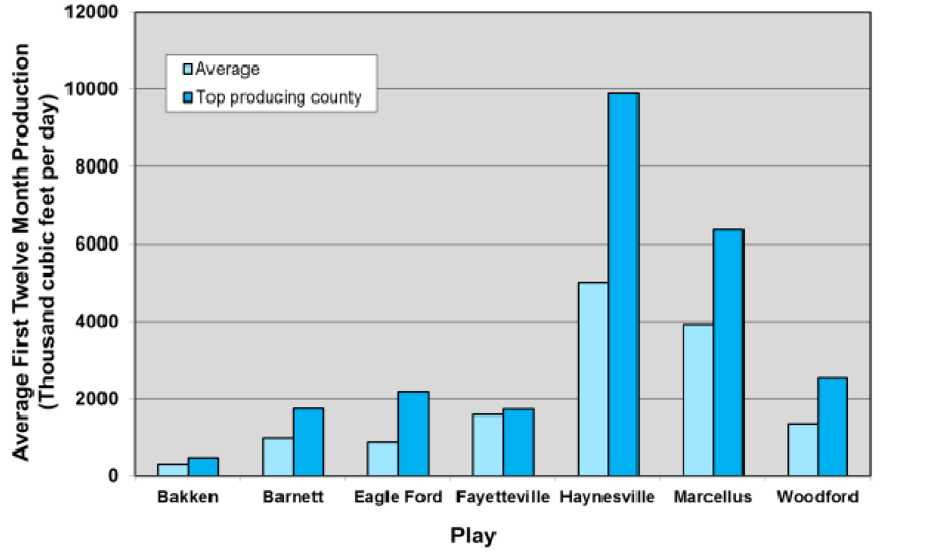



**Figure 1-5. Average first-year gas production per well in 2013 from horizontal wells both play-wide and in the top-producing county for the plays analyzed in this report.**[9]

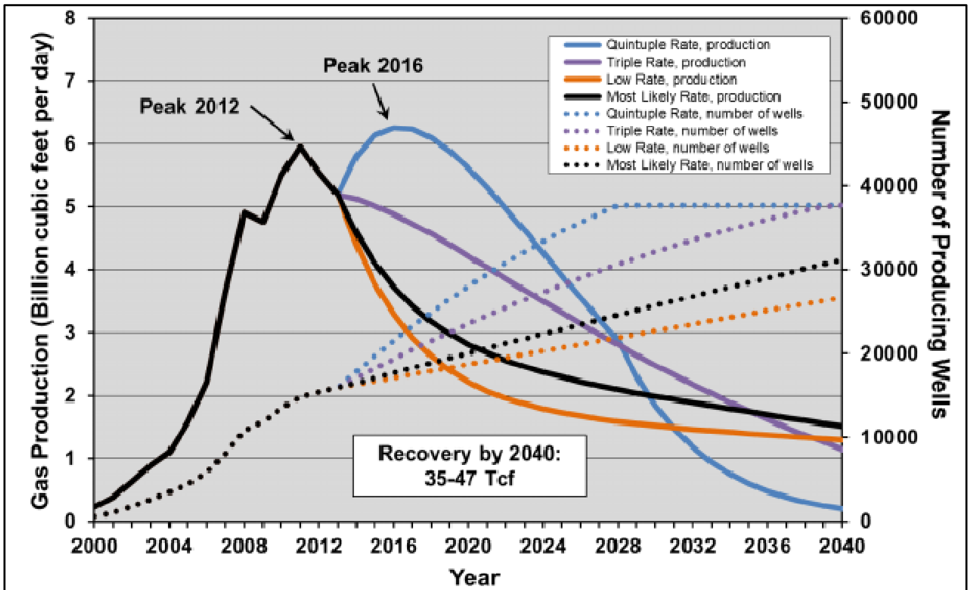



**Figure 3-25. Four drilling rate scenarios of Barnett gas production (assuming 100% of the area is drillable at eight wells per square mile).**[35]

"Most Likely Rate" scenario: drilling increases to 600 wells/year, declining to 500 wells/year.
"Low Rate" scenario: drilling continues at 400 wells/year, holding constant.
"Triple Rate" scenario: drilling increases to 1,200 wells/year, declining to 600 wells/year.
"Quintuple Rate" scenario: drilling increases to 2,000 wells/year, declining to 1,000 wells/year.
Although the peak month was December 2011, on a total year production basis the peak year is 2012.

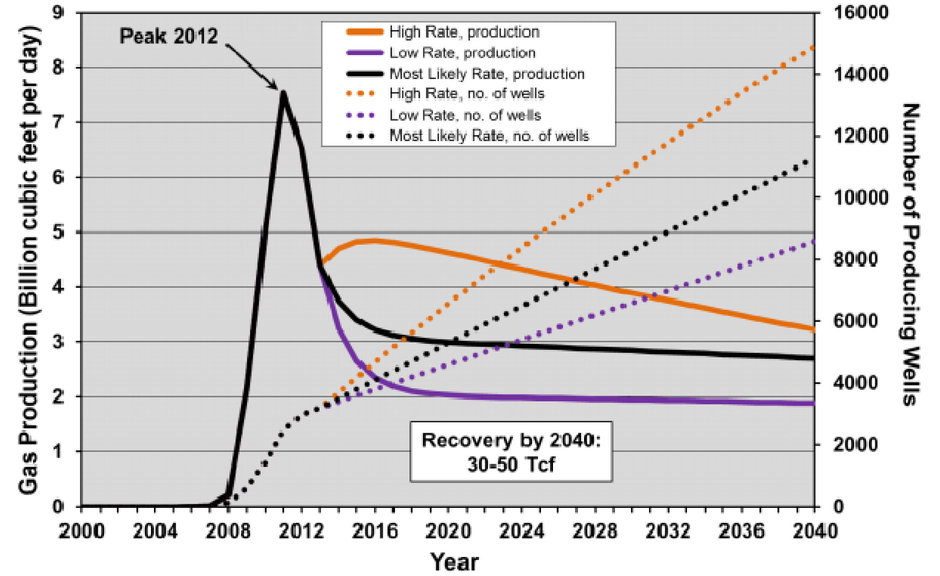



**Figure 3-43. Three drilling rate scenarios of Haynesville gas production (assuming 100% of the area is drillable at six wells per square mile).[65]**

"Most Likely Rate" scenario: drilling increases to 300 wells/year, holding constant.
"Low Rate" scenario: drilling holds constant at 200 wells/year.
"High Rate" scenario: drilling increases to 500 wells/year, declining to 300 wells/year.

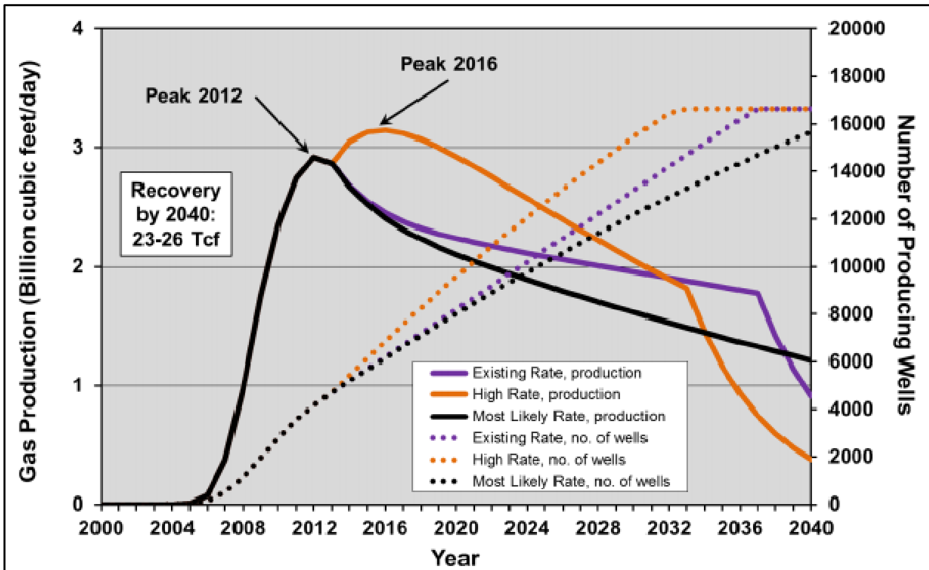



**Figure 3-59. Three drilling rate scenarios of Fayetteville gas production (assuming 100% of the area is drillable eight wells per square mile).[90]**

"Most Likely Rate" scenario: drilling holds at 500 wells/year, declining to 300 wells per year.
"Existing Rate" scenario: drilling holds constant at 500 wells/year.
"High Rate" scenario: drilling increases to 750 wells/year, declining to 500 wells/year.

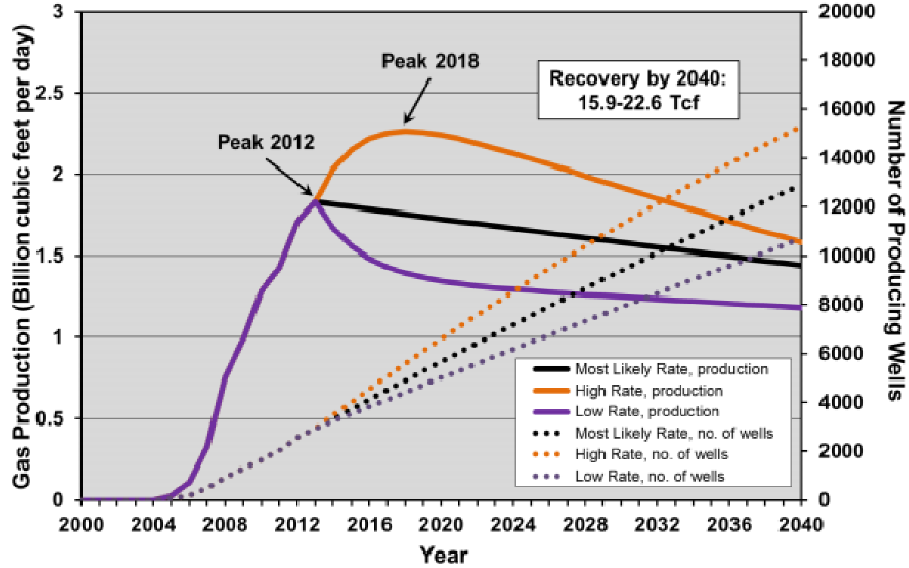



**Figure 3-78. Three drilling rate scenarios of Woodford gas production (assuming 100% of the area is drillable at 4.5 horizontal wells per square mile).[119]**

"Most Likely Rate" scenario: drilling increases to 400 wells/year, declining to 300 wells per year.
"Low Rate" scenario: drilling continues at 300 wells/year, declining to 250 wells/year.
"High Rate" scenario: drilling increases to 550 wells/year, declining to 300 wells/year.

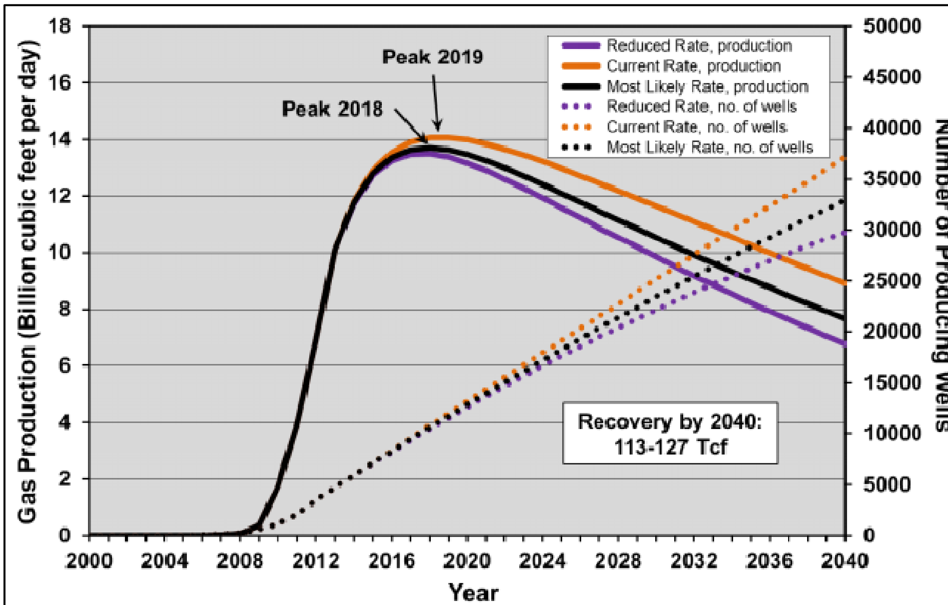



**Figure 3-98. Three drilling rate scenarios of Marcellus gas production in Pennsylvania (assuming 80% of the area is drillable at 4.3 wells per square mile).[148]**

"Most Likely Rate" scenario: drilling continues at 1,200 wells/year, declining to 800/year.
"High Rate" scenario: drilling continues at 1,200 wells/year.
"Reduced Rate" scenario: drilling continues at 1,200 wells/year, declining to 200/year.

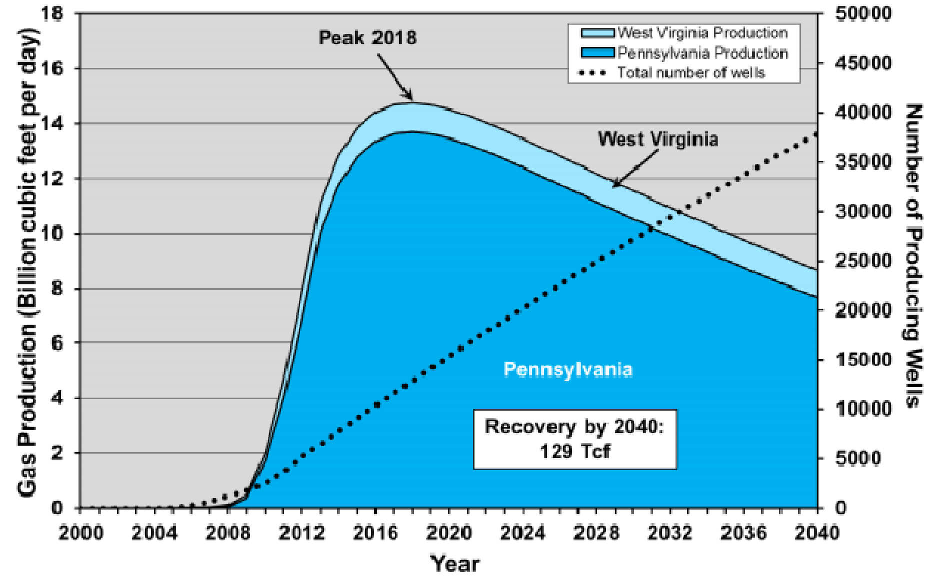



**Figure 3-99. "Most Likely Rate" scenario of Marcellus gas production including both Pennsylvania and West Virginia.**

Total recovery by 2040 of 129 Tcf is 13 times the amount of gas recovered to date. In this "Most Likely Rate scenario, with the addition of West Virginia, drilling continues at 1,320 wells/year, declining to 920/year.

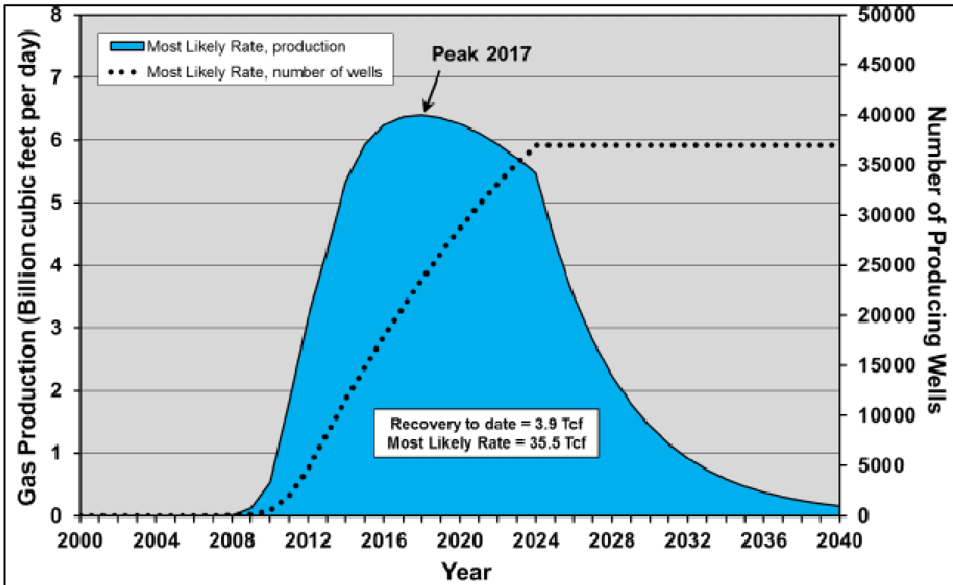



**Figure 3-106. "Most Likely Rate" scenario of Eagle Ford production for gas in the "Realistic Case" (80% of the remaining area is drillable at six wells per square mile).**

This projection assumes that well quality for gas production will rise in later stages of play development as drilling moves back into gas prone parts of the play.

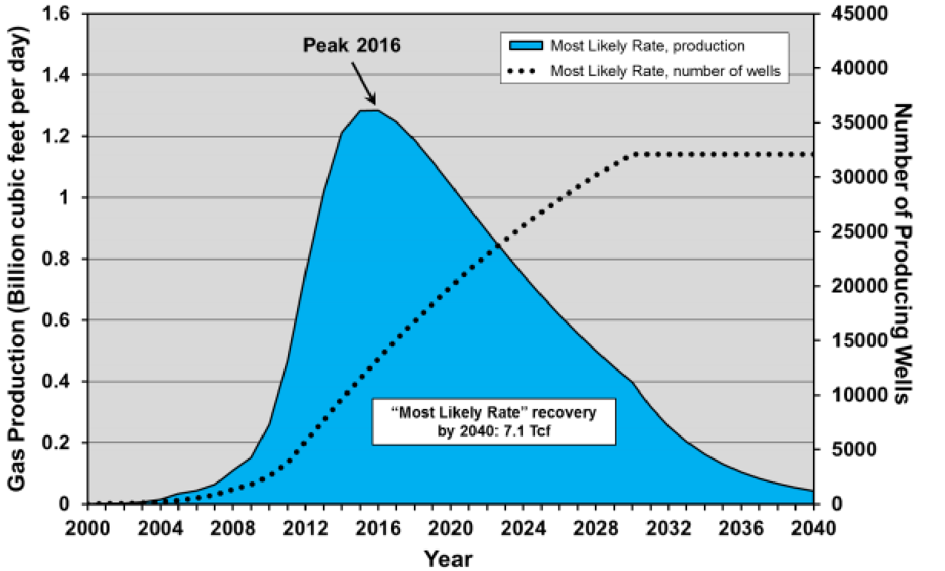



**Figure 3-112. "Most Likely Rate" scenario of Bakken gas production in the "Realistic Case" (80% of the remaining area is drillable at three wells per square mile).**

This projection assumes that well quality for gas production will parallel well quality trends for oil production as drilling moves into lower quality parts of the play.

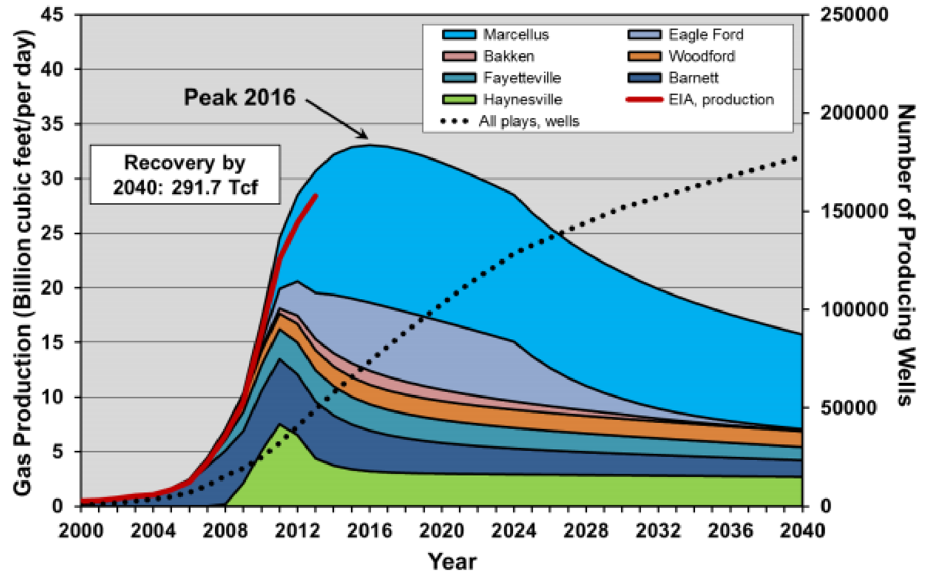
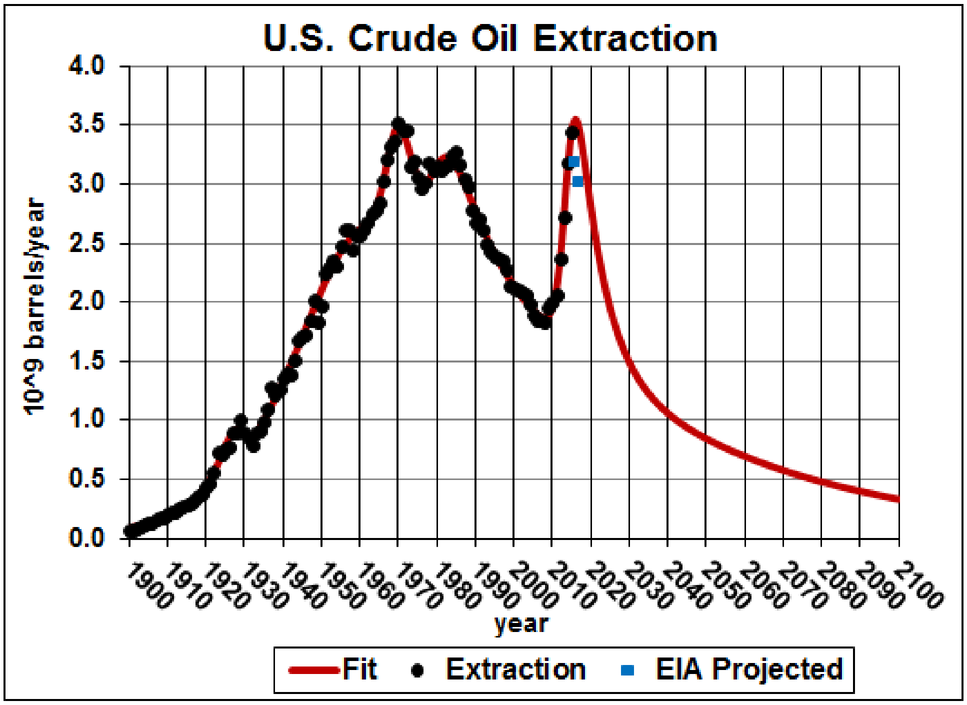



**Figure 3-115. "Most Likely Rate" scenarios for the seven shale gas plays analyzed in this report and number of producing wells, through 2040.**

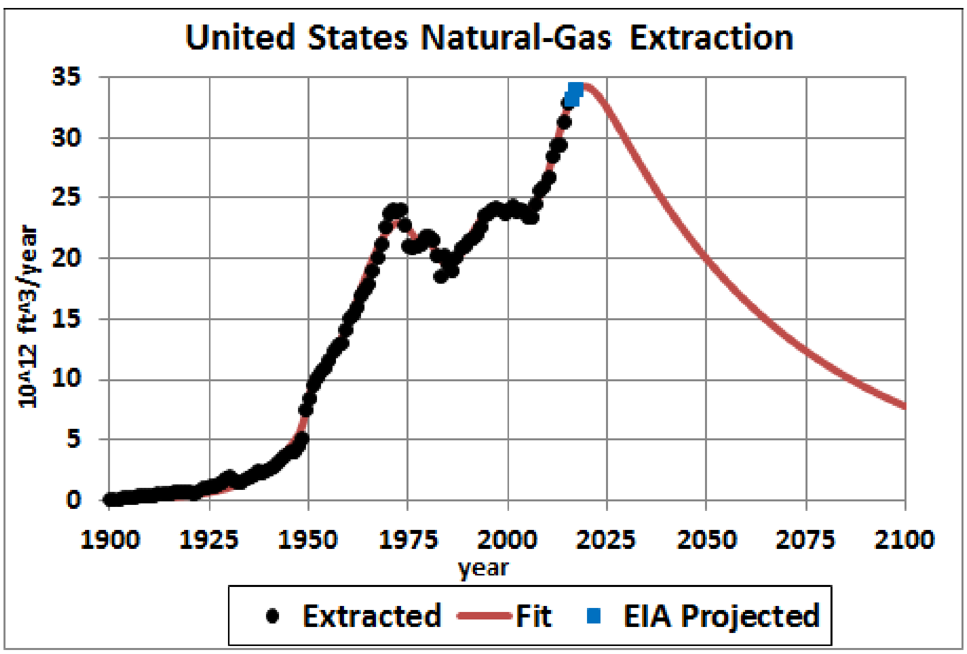
The "Most Likely Rate" scenario projections here are made on a "raw gas" basis. 180,000 wells will be producing by 2040 in this scenario. Also shown is the EIA's production data for dry gas through August 2014 for these plays.[175]

## Roper Macro-Analyses for U.S. Oil and Natural Gas Extraction

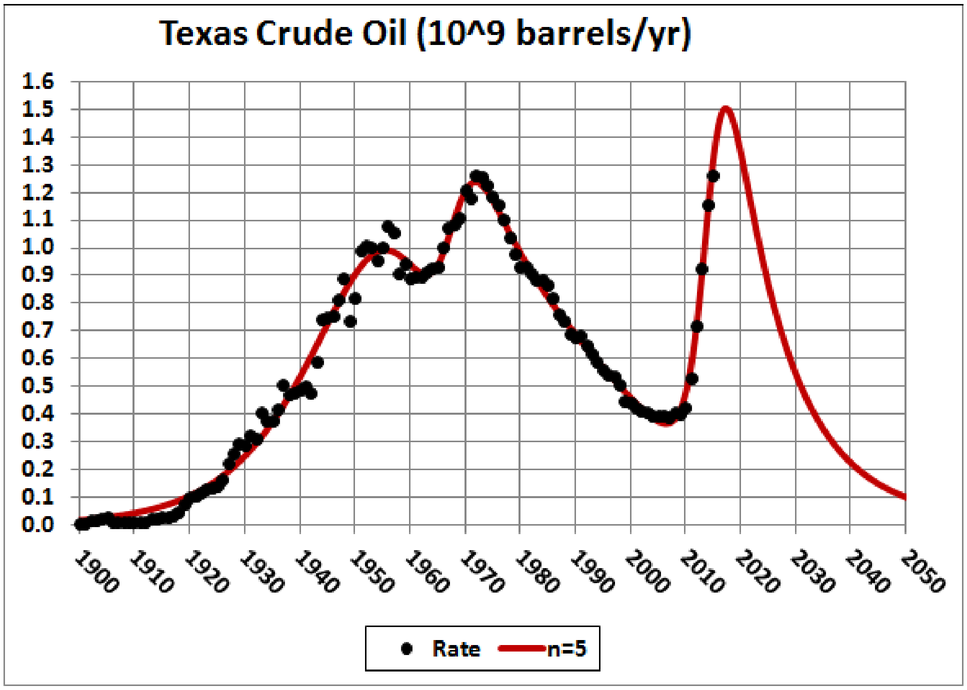
http://www.roperld.com/science/minerals/FossilFuels.htm



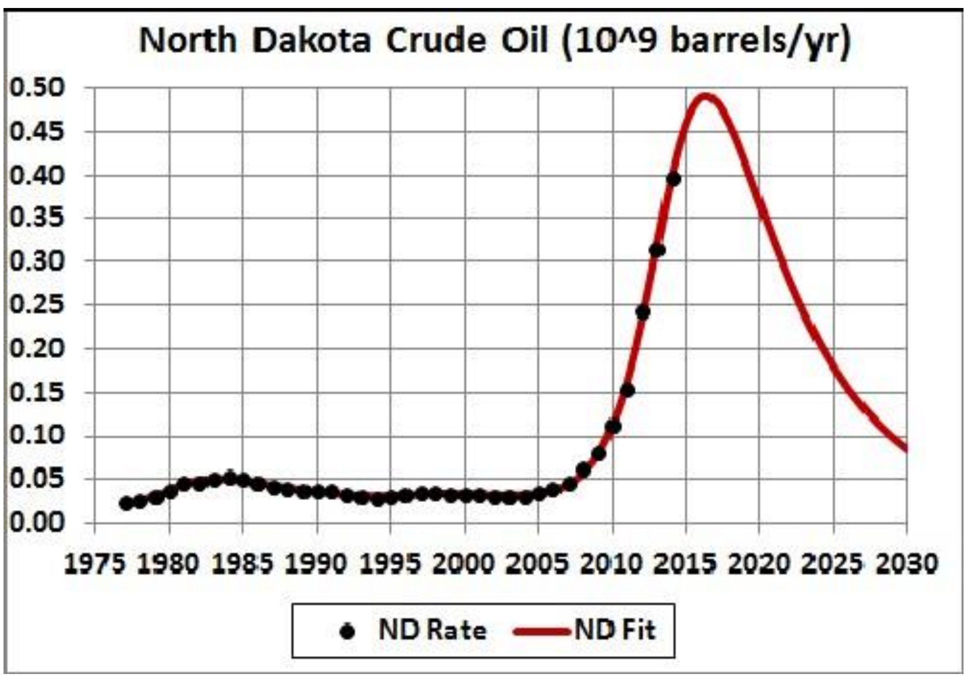

The curve's final peak has a decay exponential time constant 4.4 times the rising time constant, similar to the case for Hughes' micro-analysis for tight-oil fracking in the U.S.



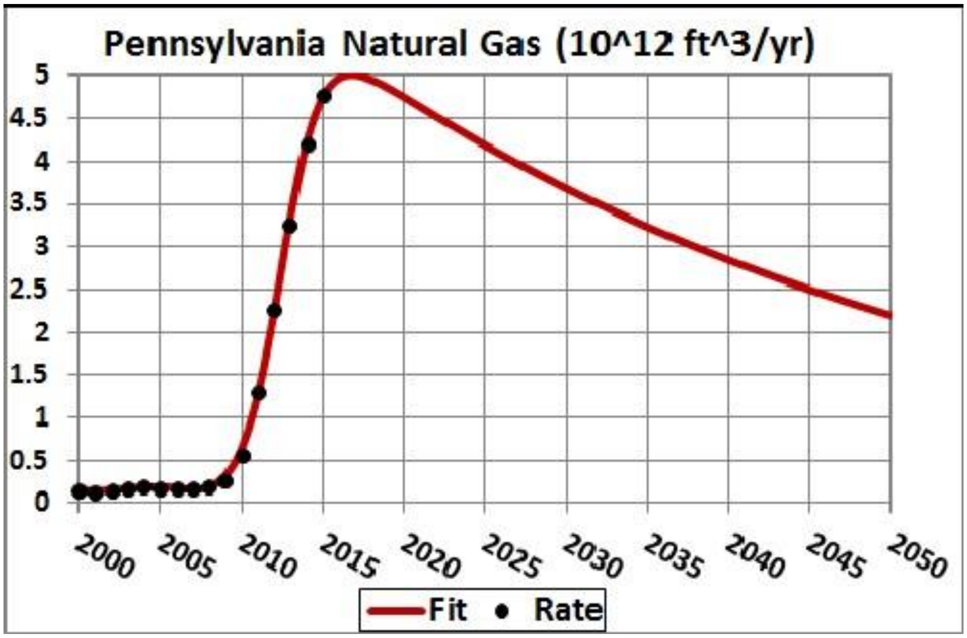

The curve's final peak has a decay exponential time constant 3.5 times the rising time constant, similar to the case for Hughes' micro-analysis for shale-gas fracking in the U.S.




The curve's final peak has a decay exponential time constant 5 times the rising time constant, similar to the case for Hughes' micro-analysis for tight-oil fracking for the Eagle Ford play.




The curve has a decay exponential time constant 3.4 times the rising time constant, similar to the case for Hughes' micro-analysis for tight-oil fracking for the Bakken play.




The curve has a decay exponential time constant 31.6 times the rising time constant, similar to the case for Hughes' micro-analysis for shale-gas fracking for the Marcellus play.