

DRILLING DEEPER

A REALITY CHECK ON U.S. GOVERNMENT FORECASTS
FOR A LASTING TIGHT OIL & SHALE GAS BOOM

PART 1: EXECUTIVE SUMMARY



J. DAVID HUGHES



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About the Author

David Hughes is a geoscientist who has studied the energy resources of Canada for four decades, including 32 years with the Geological Survey of Canada as a scientist and research manager. He developed the National Coal Inventory to determine the availability and environmental constraints associated with Canada's coal resources. As Team Leader for Unconventional Gas on the Canadian Gas Potential Committee, he coordinated the publication of a comprehensive assessment of Canada's unconventional natural gas potential. Over the past decade, Hughes has researched, published, and lectured widely on global energy and sustainability issues in North America and internationally.

In 2011, Hughes authored a series of papers on the production potential and environmental impacts of U.S. natural gas. In early 2013, he authored *Drill, Baby, Drill: Can Unconventional Fuels Usher in a New Era of Energy Abundance?*, which took a far-ranging and painstakingly researched look at the prospects for various unconventional fuels to provide energy abundance for the United States in the 21st century. In late 2013 he authored *Drilling California: A Reality Check on the Monterey Shale*, which critically examined the U.S. Energy Information Administration's (EIA) estimates of technically recoverable tight oil in the Monterey Shale, which the EIA claimed constituted two-thirds of U.S. tight oil; the EIA subsequently wrote down its resource estimate for the Monterey by 96%. In early 2014 he authored *BC LNG: A Reality Check*, which examined the issues surrounding the proposed massive scale up of shale gas production in British Columbia for LNG export.

Hughes is president of Global Sustainability Research, a consultancy dedicated to research on energy and sustainability issues. He is also a board member of Physicians, Scientists & Engineers for Healthy Energy (PSE Healthy Energy) and is a Fellow of Post Carbon Institute. Hughes contributed to *Carbon Shift*, an anthology edited by Thomas Homer-Dixon on the twin issues of peak energy and climate change, and his work has been featured in *Nature*, *Canadian Business*, *Bloomberg*, *USA Today*, as well as other popular press, radio, and television.

About Post Carbon Institute

Post Carbon Institute's mission is to lead the transition to a more resilient, equitable, and sustainable world by providing individuals and communities with the resources needed to understand and respond to the interrelated economic, energy, and ecological crises of the 21st century.

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

By J. David Hughes

In association with Post Carbon Institute

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For reprint requests and other inquiries, contact:

Post Carbon Institute, 613 Fourth St., Suite 208, Santa Rosa, California, 95404

PART 1: EXECUTIVE SUMMARY

By Asher Miller, Executive Director, Post Carbon Institute

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1.1 INTRODUCTION

In recent years Americans have been hearing that the United States is poised to regain its role as the world's premier oil and natural gas producer, thanks to the widespread use of horizontal drilling and hydraulic fracturing ("fracking"). This "shale revolution," we're told, will fundamentally change the U.S. energy picture for decades to come—leading to energy independence, a rebirth of U.S. manufacturing, and a surplus supply of both oil and natural gas that can be exported to allies around the world. This promise of oil and natural gas abundance is influencing climate policy, foreign policy, and investments in alternative energy sources.

The primary source for these rosy expectations of future production is the U.S. Department of Energy (DOE). Each year the DOE's Energy Information Administration (EIA) releases its *Annual Energy Outlook* (AEO)¹, which provides a range of forecasts for energy production, consumption, and prices.

The 2014 AEO reference case projects U.S. crude oil production to rise to 9.6 million barrels of oil per day (MMbbl/d) in 2019 and slowly decline to 7.5 MMbbl/d by 2040, while natural gas production is projected to grow for at least the next 25 years and hit 37.5 trillion cubic feet per year in 2040. Tight oil (shale oil) and shale gas serve as the foundation for these optimistic forecasts.

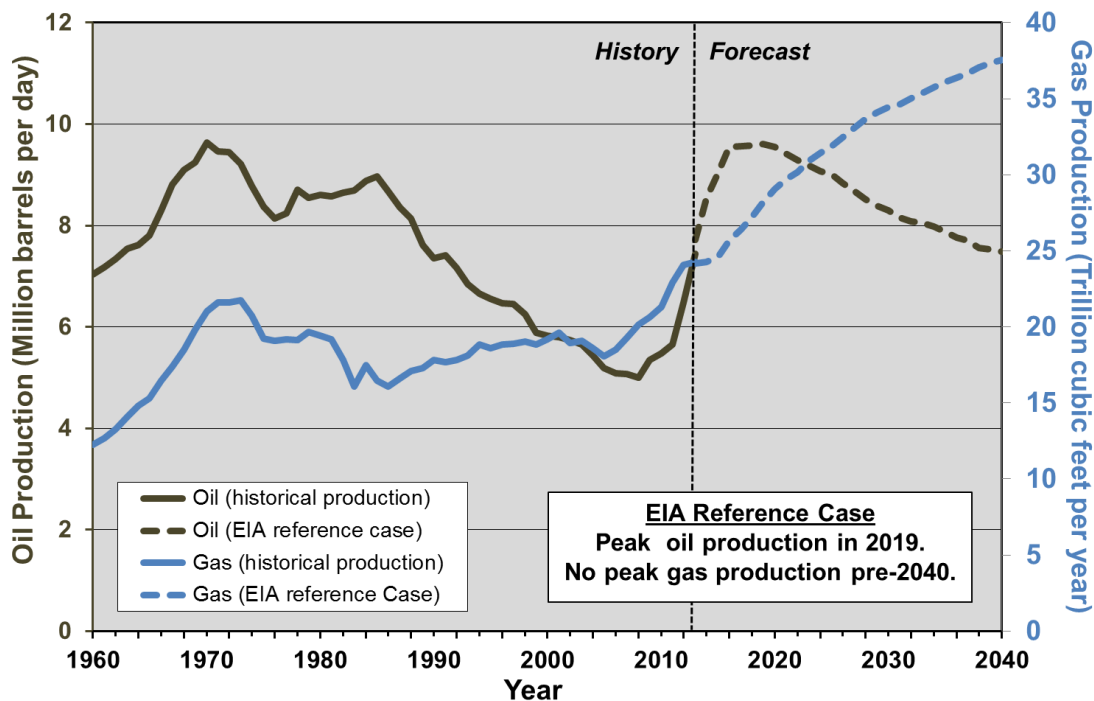


Figure 1-1. History and EIA reference case forecast of U.S. oil and natural gas production, 1960 to 2040.²

¹ EIA, *Annual Energy Outlook 2014*, <http://www.eia.gov/forecasts/aeo/>.

² EIA, *Annual Energy Outlook 2014*, <http://www.eia.gov/forecasts/aeo/>.

This report provides an extensive analysis of actual production data from the top seven tight oil and seven shale gas plays in the U.S. (These plays account for 89% of current tight oil production and 88% of current shale gas production, and serve as the primary sources of future production in the EIA's forecasts—82% of forecast tight oil and 88% of forecast shale gas production through 2040.) It concludes that the current boom in domestic oil and gas production is unsustainable at the rates projected by the EIA, and that the EIA's tight oil and shale gas forecasts to 2040 are extremely optimistic. What this means is that the country's current energy policy—which is largely based on the expectation of domestic oil and natural gas abundance far into the future—is badly misguided and is setting the country up for a painful, costly, and unexpected shock when the boom ends.

1.2 ABOUT THE REPORT

Drilling Deeper: A Reality Check on U.S. Government Forecasts for a Lasting Shale Boom was authored by J. David Hughes on behalf of Post Carbon Institute. The report investigates whether the EIA's expectation of long-term domestic oil and natural gas abundance is founded. It aims to gauge the likely future of U.S. tight oil and shale gas production based on an in-depth assessment of actual well production data from the major shale plays. The primary source of data for this analysis is Drillinginfo, a commercial database of well production data widely used by industry and government, including the EIA.³ Drillinginfo also provides a variety of analytical tools which proved essential for the analysis.

This analysis is based on all drilling and production data available through early- to mid-2014. The report determined future production profiles given assumed rates of drilling, average well quality by area, well- and field-decline rates, and the estimated number of available drilling locations. The plays analyzed (which collectively account for 89% of current tight oil production and 88% of current shale gas production) are as follows:

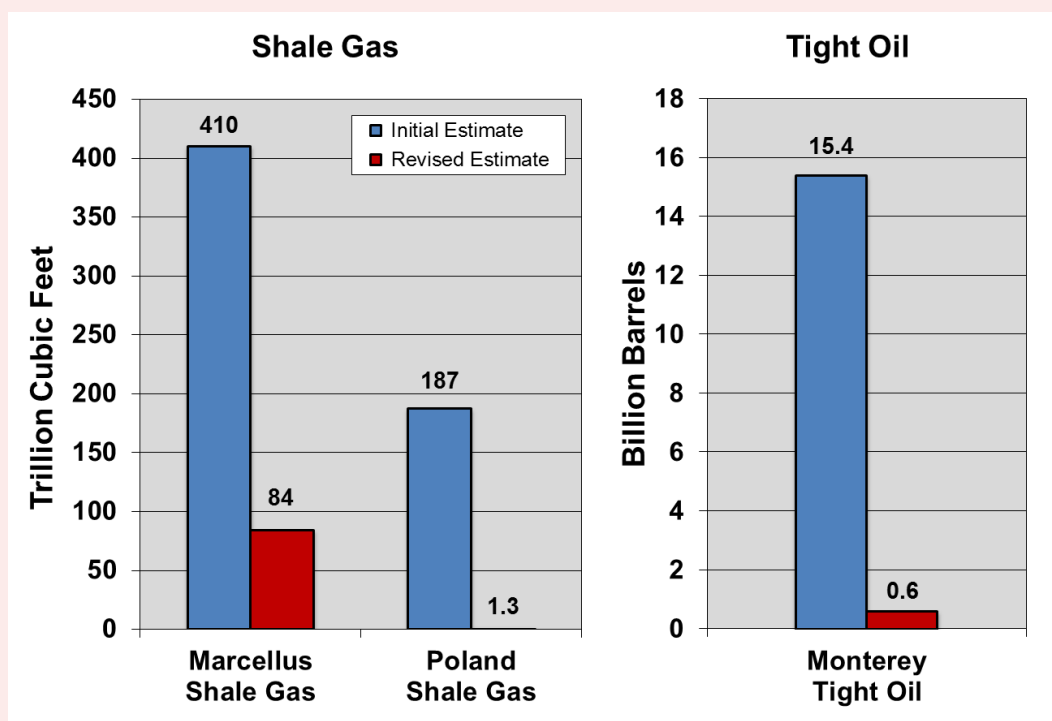
Tight Oil Plays⁴	Shale Gas Plays
Bakken (North Dakota and Montana)	Barnett (Texas)
Eagle Ford (Texas)	Haynesville (Louisiana and Texas)
Spraberry (Texas)	Fayetteville (Arkansas)
Wolfcamp (Texas and New Mexico)	Woodford (Oklahoma)
Bone Spring (Texas and New Mexico)	Marcellus (Pennsylvania and West Virginia)
Austin Chalk (Gulf Coast Region)	Bakken (North Dakota and Montana; associated gas)
Niobrara (Colorado and Wyoming)	Eagle Ford (Texas; associated gas)

³ See <http://info.drillinginfo.com>.

⁴ The Monterey tight oil play in California was assessed in a previous report by this same author: J. David Hughes, *Drilling California: A Reality Check on the Monterey Shale*, Post Carbon Institute, 2013, <http://www.postcarbon.org/publications/drilling-california>.

The EIA's Poor Track Record

Policymakers, media, investors, and the general public typically receive the Department of Energy's EIA forecasts with little to no circumspection, despite their poor track record. In 2011, the EIA was forced to cut its estimates of technically recoverable shale gas in the Marcellus play by 80%¹ and in Poland by 99%² after the United States Geological Survey came out with much lower numbers. At the time of the Marcellus downgrade, an EIA spokesperson said, "We consider the USGS to be the experts in this matter... They're geologists, we're not. We're going to be taking this number and using it in our model."³ In early 2014, the EIA slashed its estimate of technically recoverable tight oil from California's Monterey Formation by a whopping 96%.⁴ Just three years previously, the agency had estimated it held fully two-thirds of all U.S. tight oil. The author of the original EIA estimate, INTEK Inc., admitted that it had been derived from oil company presentations rather than hard data.⁵ The EIA's downgrade occurred after this report's author, J. David Hughes, published an analysis six months earlier that showed—using actual production data from the Monterey Formation—that the EIA's estimates were wildly optimistic.⁶



Initial EIA estimates of shale resources vs. revised estimates.

¹ Efstathiou, J. and Klimasinska, K., 23 August 2011, *Bloomberg*, "U.S. to Slash Marcellus Shale Gas Estimate 80%," <http://www.bloomberg.com/news/2011-08-23/u-s-to-slash-marcellus-shale-gas-estimate-80-.html>.

² Blake, M., September/October 2014, *Mother Jones*, "How Hillary Clinton's State Department Sold Fracking to the World," <http://www.motherjones.com/environment/2014/09/hillary-clinton-fracking-shale-state-department-chevron>.

³ Efstathiou, J. and Klimasinska, K., "U.S. to Slash Marcellus Shale Gas Estimate 80%."

⁴ Sahagun, L., 20 May 2014, *Los Angeles Times*, "U.S. officials cut estimate of recoverable Monterey Shale oil by 96%," <http://www.latimes.com/business/la-fi-oil-20140521-story.html>.

⁵ Kern Golden Empire, 3 December 2013, "Report: Monterey Shale production 'wildly optimistic'," <http://www.kerngoldenempire.com/story/report-monterey-shale-production-wildly-optimistic/d/story/VdOYdQZ-4UKgp7qNwqq8Xg>.

⁶ Hughes, J.D., 2013, *Drilling California: A Reality Check on the Monterey Shale*, Post Carbon Institute, <http://www.postcarbon.org/publications/drilling-california>.

1.3 KEY FINDINGS

The seven tight oil plays and seven shale gas plays analyzed in this report account for 82% of projected tight oil production and 88% of projected shale gas production through 2040 in the EIA's *Annual Energy Outlook 2014* reference case forecast. A detailed analysis of well production data from these plays resulted in these key findings:

- 1) Tight oil production from major plays will peak before 2020. Barring major new discoveries on the scale of the Bakken or Eagle Ford, production will be far below EIA's forecast by 2040.
 - a) Tight oil production from the two top plays, the Bakken and Eagle Ford, will underperform EIA's reference case oil recovery by 28% from 2013 to 2040, and more of this production will be front-loaded than the EIA estimates.
 - b) By 2040, production rates from the Bakken and Eagle Ford will be less than a tenth of that projected by EIA.
 - c) Tight oil production forecast by the EIA from plays other than the Bakken and Eagle Ford is in most cases highly optimistic and unlikely to be realized at the rates projected.
- 2) Shale gas production from the top seven plays will likely peak before 2020. Barring major new discoveries on the scale of the Marcellus, production will be far below EIA's forecast by 2040.
 - a) Shale gas production from the top seven plays will underperform EIA's reference case forecast by 39% from 2014 to 2040 period, and more of this production will be front-loaded than EIA estimates.
 - b) By 2040, production rates from these plays will be about one-third that of the EIA forecast.
 - c) Production from shale gas plays other than the top seven will need to be four times that estimated by EIA in order to meet its reference case forecast.
- 3) Over the short term, U.S. production of both shale gas and tight oil is projected to be robust—but a thorough review of the production data indicate that this will be unsustainable in the longer term. These findings have clear implications for current domestic and foreign policy discussions, which generally assume decades of U.S. oil and gas abundance.

Other factors that could limit production are public pushback as a result of health and environmental concerns, and capital constraints that could result from lower oil or gas prices or higher interest rates. As such factors have not been included in this analysis, the findings of this report represent a “best case” scenario for market, capital, and political conditions.

1.3.1 Tight Oil

The analysis shows that U.S. tight oil production cannot be maintained at the levels assumed by the EIA beyond 2020. The top two plays—Bakken and Eagle Ford—which account for more than 60% of current production, are likely to peak by 2017 and the remaining plays will make up considerably less of future production than has been forecast by the EIA. Rather than a peak in 2021 followed by a gradual decline to slightly below today's levels by 2040, total U.S. tight oil production is likely to peak before 2020 and decline to a small fraction of today's production levels by 2040.

1.3.1.1 General Findings

- The 3-year average well decline rates in the seven plays analyzed for this report (which collectively provide 89% of current U.S. tight oil production) range from 60% to 91%.
- The high decline rates of tight oil wells in these plays means that 43% to 64% of their estimated ultimate recovery (EUR) is recovered in the first three years.
- Field declines from the Bakken and Eagle Ford are 45% and 38% per year, respectively (this compares to 5% per year for large conventional fields). This is the amount of production that must be replaced each year with more drilling in order to maintain production at current levels (field decline is made up of all wells in a play—old and new—and hence is lower than first-year well declines).
- 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	Optimism Bias Rating of EIA's Forecast
Bakken	85%	High
Eagle Ford	79%	High
Spraberry	60%	Very High
Wolfcamp	81%	High
Bone Spring	91%	Low
Austin Chalk	85%	Very High
Niobrara	90%	High

- The EIA assumes that the equivalent of 100% of proved reserves and between 65% and 85% of its “unproved technically recoverable tight oil resources” will be recovered by 2040 for the plays analyzed. Considering that unproved, technically recoverable resources have no price constraints and only loose geological constraints, this is highly speculative.
- The EIA assumes that the U.S. will exit 2040 with tight oil production at levels only marginally less than today, at 3.2 MMbbl/d. A thorough analysis of the well production data suggests this is highly optimistic.

1.3.1.2 Forecasts for Bakken & Eagle Ford Tight Oil Plays

- The EIA's forecast of the timing of peak production in the Bakken and Eagle Ford is similar to this report, as is the rate of peak production.
- The EIA forecasts a much higher tail after peak production, with recovery of 19.2 billion barrels between 2012 and 2040, as opposed to 13.9 billion barrels forecast in this report.
- The EIA forecasts collective production from the Bakken and Eagle Ford to be a little over 1 million barrels per day in 2040. In contrast, the "Most Likely" drilling rate scenario presented in this report forecasts that production will fall to about 73,000 barrels per day by 2040.

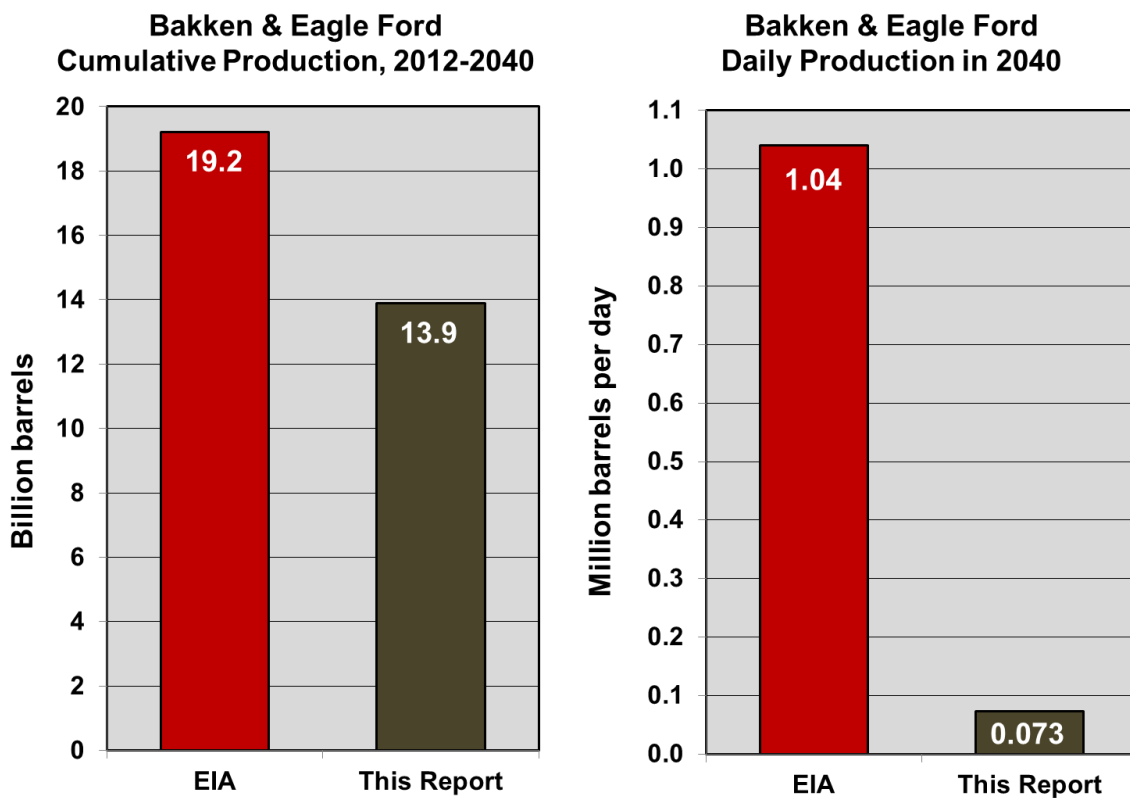


Figure 1-2. Bakken and Eagle Ford plays projected cumulative oil production from 2012 to 2040 and daily oil production in 2040, EIA projection⁵ versus this report's projection.

⁵ EIA, *Annual Energy Outlook 2014*, <http://www.eia.gov/forecasts/aeo>.

1.3.1.3 Forecasts for Other Tight Oil Plays

- To meet the EIA's forecasts, all other plays together would need to produce over twice as much through 2040 as what is projected for the Bakken and Eagle Ford.

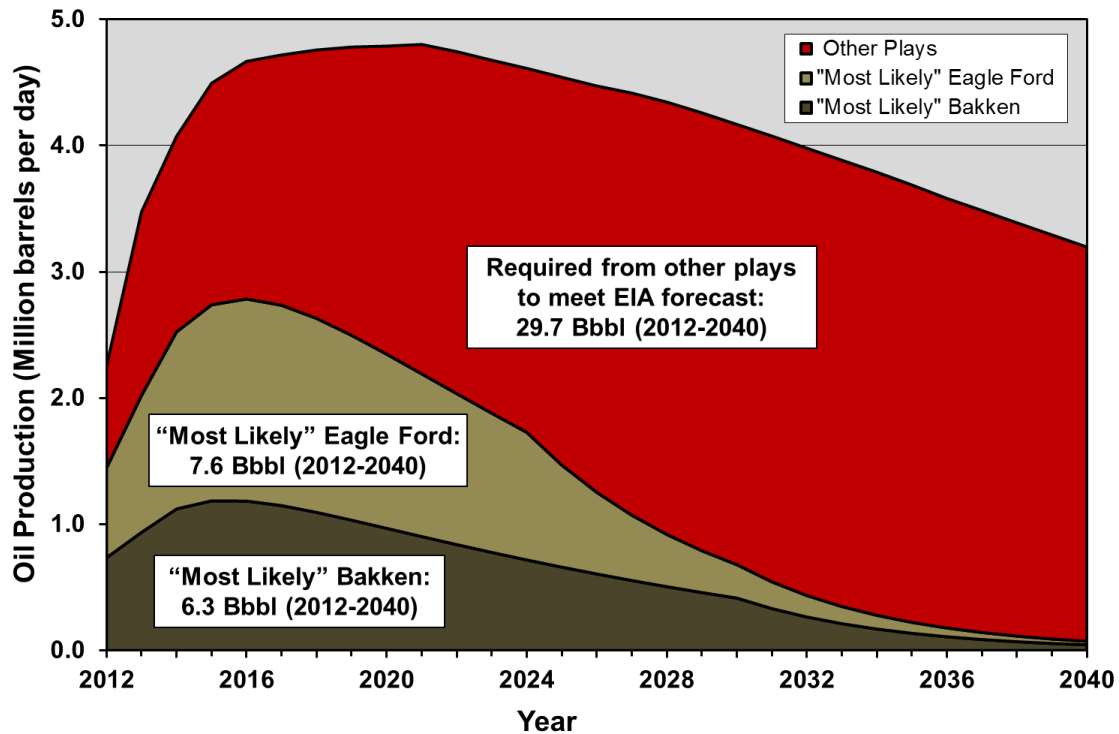


Figure 1-3. “Most Likely” scenario projections of oil production for the Bakken and Eagle Ford plays⁶ with the remaining amount of production that would be required from other plays to meet the EIA’s total reference case forecast.⁷

The EIA forecasts 43.6 billion barrels of U.S. tight oil will be recovered from 2012 to 2040. After subtracting the 13.9 billion barrels projected by this report for the Bakken and Eagle Ford, 29.7 billion barrels would remain to be produced from all other tight oil plays—5.3 billion barrels more than the EIA’s already optimistic forecast for these plays.

⁶ Data from Drillinginfo retrieved July 2014.

⁷ EIA, *Annual Energy Outlook 2014*, Unpublished tables from AEO 2014 provided by the EIA.

- The major remaining tight oil plays are the three Permian Basin plays—Spraberry, Wolfcamp, and Avalon/Bone Spring—plus the Austin Chalk and the Niobrara. EIA forecasts expect these plays to produce four to five times their historical production in the next 26 years, but this is highly questionable, considering that:
 - These plays are already 40-60 years old, with tens of thousands of wells already drilled.
 - The Permian Basin plays' average initial well productivities are half or less the average of core counties in the Bakken or Eagle Ford.
 - The Bakken and Eagle Ford's average estimated ultimate recovery (EUR) per well is two to more than six times higher than that of these other plays.

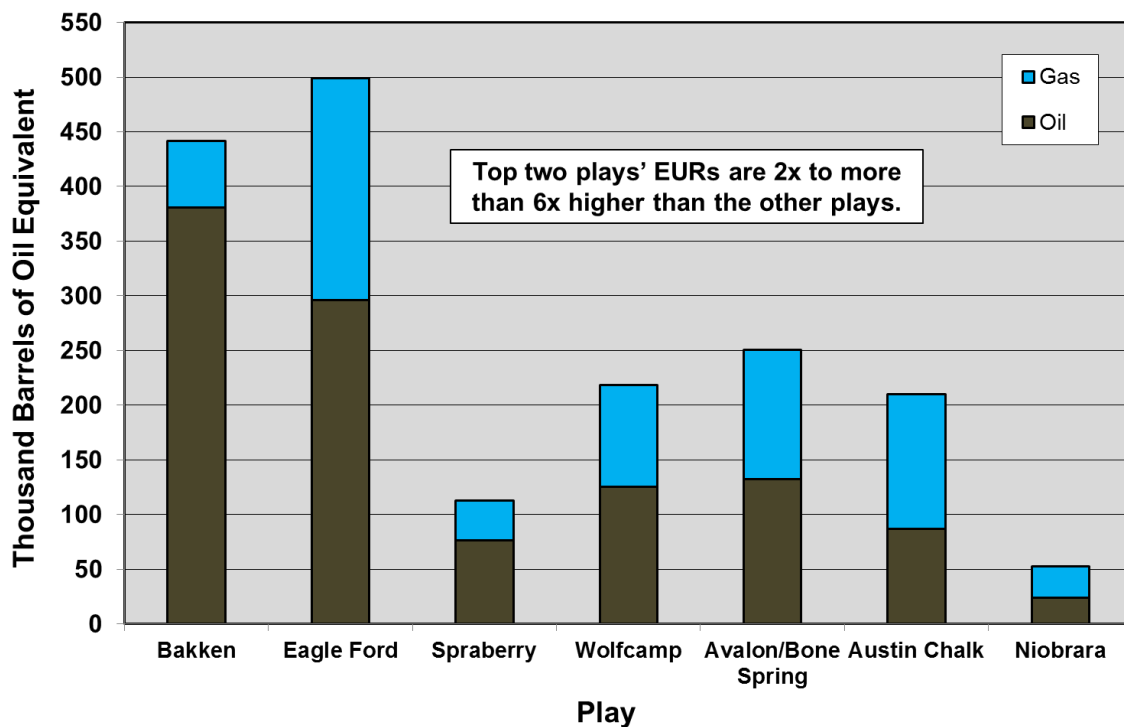


Figure 1-4. Estimated ultimate recovery (EUR) of oil and gas per well of reviewed plays, on a “barrels of oil equivalent” basis.⁸

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).

⁸ Based on data from Drillinginfo retrieved May-July 2014.

1.3.2 Shale Gas

The EIA now projects domestic gas production to reach nearly 38 trillion cubic feet per year by 2040, which is 55% above 2013 levels. The bulk of this production growth would come from shale gas.

This analysis shows that simply maintaining U.S. shale gas production in the medium term—let alone increasing production at rates forecast by the EIA through 2040—will be problematic. Four of the top seven shale gas plays are already in decline. Of the major plays, only the Marcellus, Eagle Ford, and Bakken (the latter two are tight oil plays producing associated gas) are growing; and yet, the EIA reference case gas forecast calls for plays currently in decline to grow to new production highs, at moderate future prices. Although significantly higher gas prices needed to justify higher drilling rates could temporarily reverse decline in some of these plays, the EIA forecast is unlikely to be realized.

1.3.2.1 General Findings

- The 3-year average well decline rates in the seven plays analyzed for this report (which collectively provide 88% of U.S. shale gas production) ranges between 74% and 82%.
- The average field decline rates for these plays ranges between 23% and 49%, meaning that between one-quarter and one-half of all production in each play must be replaced each year in order to simply maintain current production.
- Although the EIA forecast for the Marcellus play is rated as “reasonable” and its forecast for the Bakken play is rated “conservative,” the deficit left by being “very highly optimistic” on some of the other plays makes finding and developing the gas required to meet the overall forecast unlikely.

Play	Average 3-Year Well Decline Rate	Average First-Year Field Decline Rate	Optimism Bias Rating of EIA's Forecast
Barnett	75%	23%	Very High
Haynesville	88%	49%	Very High
Fayetteville	79%	34%	Very High
Woodford	74%	34%	High
Marcellus	74-82%	32%	Reasonable
Eagle Ford	80%	47%	Very high
Bakken	81%	41%	Conservative

- Because productivity of shale wells declines rapidly, many new wells must be drilled just to maintain existing production levels. Of the top shale gas plays, only the Marcellus, Eagle Ford, and Bakken are currently seeing enough drilling to maintain and grow production.

- Major shale gas plays are variable in well quality. The Marcellus and Haynesville are much more productive on average than the other plays analyzed in this report. Even within plays, well quality varies considerably.

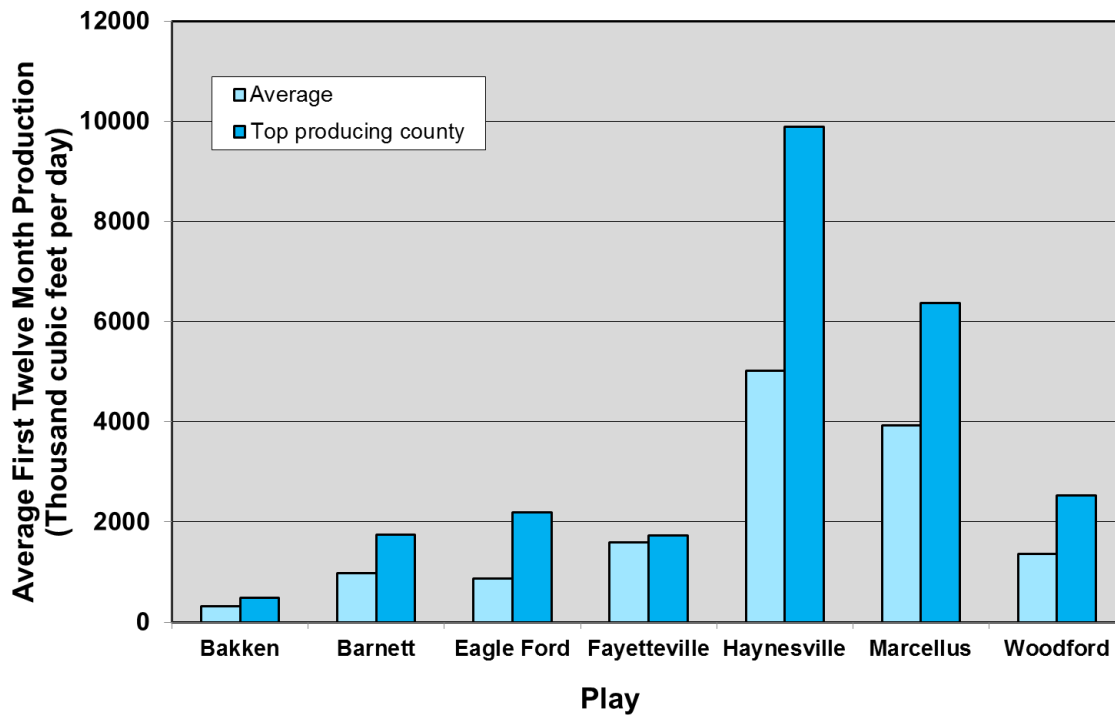


Figure 1-5. Average first-year gas production per well in 2013 from horizontal wells both play-wide and in the top-producing county for the plays analyzed in this report.⁹

⁹ Data from Drillinginfo retrieved August to September 2014.

- Despite years of concerted efforts and claims that technological innovation can overcome steep well decline rates and the move from “sweet spots” to lower quality parts of plays, average well productivity has gone flat in all major shale gas plays except the Marcellus.

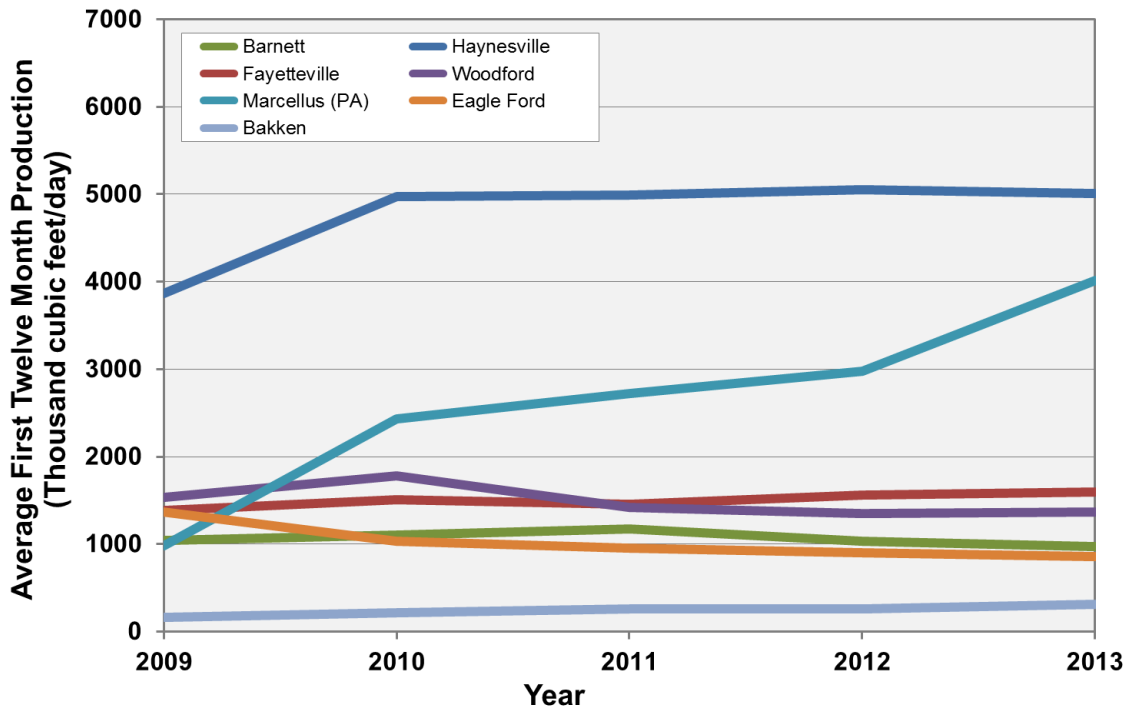


Figure 1-6. Average production over first twelve months per well for major U.S. shale gas plays.¹⁰

- Approximately 130,000 additional shale gas wells will need to be drilled by 2040 to meet the projections of this report, on top of the 50,000 wells drilled in these plays through 2013. Assuming an average well cost of \$7 million, this would require \$910 billion of additional capital input by 2040, not including leasing, operating, and other ancillary costs.

¹⁰ Data from Drillinginfo retrieved August 2014.

1.3.2.2 Forecasts for Shale Gas Plays

- The EIA assumes that 74% to 110% of its “unproved technically recoverable resources” plus “proved reserves” will be recovered by 2040 for the seven major plays analyzed. Considering that unproved, technically recoverable resources have no price constraints and only loose geological constraints, this is highly speculative.
- This analysis found that the EIA reference case forecast for the top seven shale gas plays overestimates cumulative production through 2040 in this report’s “Most Likely” scenario by 64%.
- The EIA further estimates that in 2040, shale gas production from the seven plays analyzed will be 182% higher (nearly 3 times) than estimated in this report—and that by 2040, another 49.6 Tcf will have been recovered from other plays not analyzed in this report.

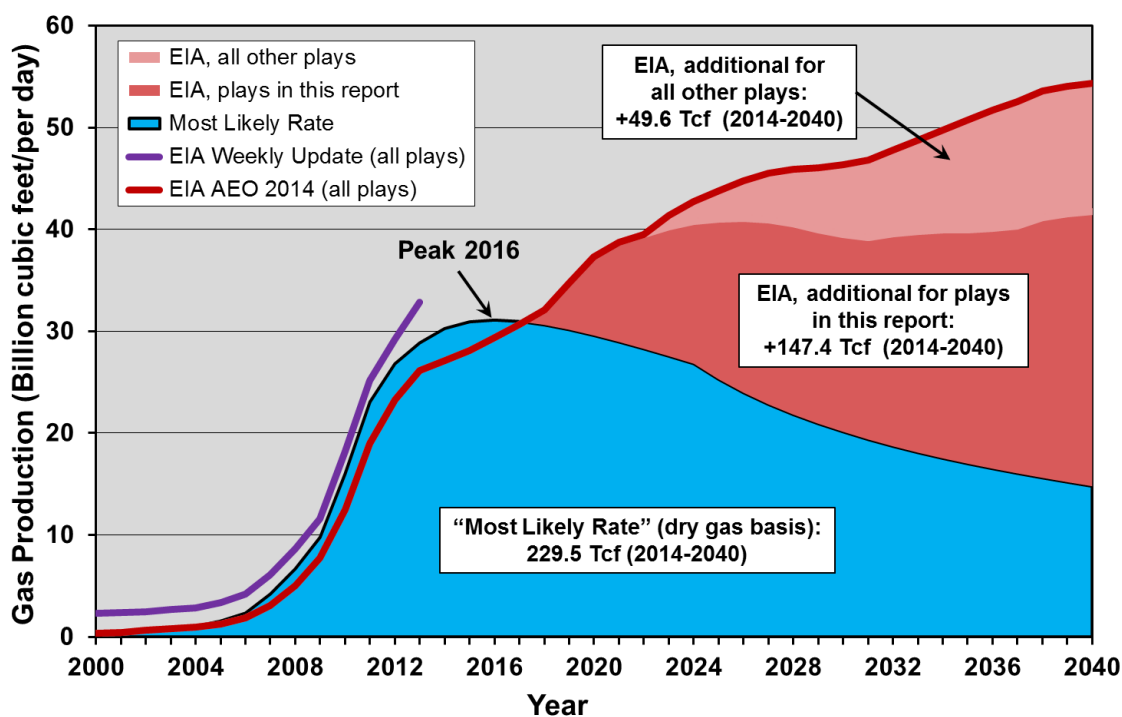


Figure 1-7. Totaled “Most Likely Rate” scenarios for the seven plays analyzed in this report, compared to the EIA’s reference case forecast for these plays and for all plays.^{11,12}

The “Most Likely Rate” scenario projections here are made on a “dry gas” basis. Also shown are the EIA’s gas production statistics from its *Natural Gas Weekly Update*,¹³ which contradict the early years of its AEO 2014 forecast.

¹¹ EIA, *Annual Energy Outlook 2014*, unpublished tables from AEO 2014 provided by the EIA.

¹² EIA, *Annual Energy Outlook 2014*, reference case forecast, Table 14, oil and gas supply, http://www.eia.gov/forecasts/aeo/excel/aeotab_14.xlsx.

¹³ EIA, *Natural Gas Weekly Update*, retrieved October 2014, <http://www.eia.gov/naturalgas/weekly>.

- In this report's "Most Likely" scenario, cumulative dry shale gas production over the 2014-2040 period is 229.5 trillion cubic feet (Tcf)—46% lower than the EIA Reference Case (377 Tcf).
- In this report's "Most Likely" scenario, shale gas production from the seven plays analyzed peaks in the 2016-2017 timeframe and declines by more than half, to 14.8 billion cubic feet per day (Bcf/d) by 2040. In contrast, the EIA expects production from these plays to keep growing through 2040, with shale gas production in that year at 41.8 Bcf/d—nearly three times higher than this report finds justifiable.

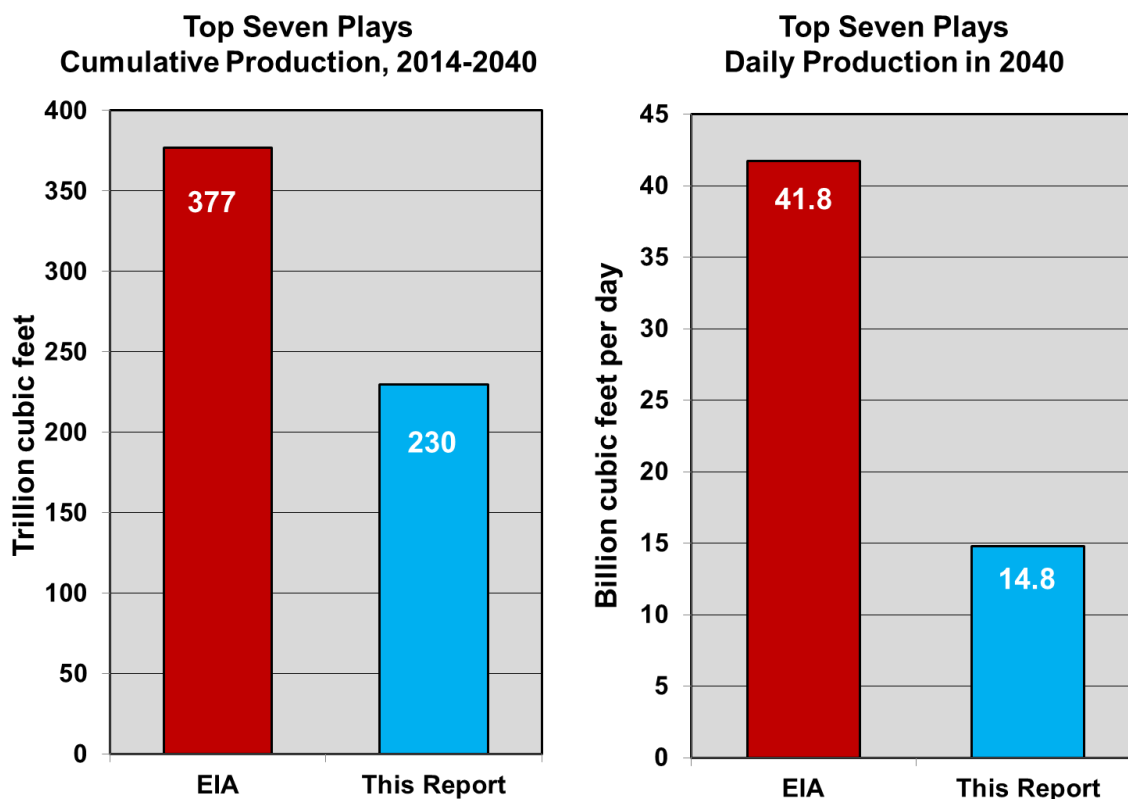


Figure 1-8. Projected cumulative gas production to 2040 and daily gas production in 2040, EIA projection¹⁴ versus this report's projection.

The values given here are for the seven plays analyzed in this report. These plays constitute 88% of cumulative U.S. shale gas production from 2014 to 2040 in the EIA's reference case forecast.

¹⁴ EIA, *Annual Energy Outlook 2014*, <http://www.eia.gov/forecasts/aeo>.

1.4 IMPLICATIONS

This report shows that the EIA's optimistic forecasts for future U.S. tight oil and shale gas production are based on a set of **false premises**, namely that:

- High-quality shale plays are ubiquitous, and there will be always be new discoveries and production from emerging plays to fill the gap left by declining production from major existing plays.
- Technological advances can overcome steep decline rates and declining well quality as drilling moves from sweet spots to poorer quality rock, in order to maintain high production rates.
- Large estimated resources underground imply high and durable rates of extraction over decades.

Actual production data from the past decade of shale gas and tight oil drilling clearly do not support these assumptions. Unfortunately, the EIA's rosy forecasts have led policymakers and the American public to believe a number of **false promises**:

- That cheap and abundant natural gas supplies can create a domestic manufacturing resurgence and millions of new jobs over the long term.¹⁵
- That abundant domestic oil and natural gas resources justify lifting the oil export ban (imposed 40 years ago after the Arab oil embargo)¹⁶ and fast-tracking approval of liquefied natural gas (LNG) export terminals.¹⁷
- That the U.S. can use its newfound energy strength to shift geopolitical trends in our long-term favor.¹⁸
- That we can easily limit carbon dioxide emissions from power plants as a result of natural gas replacing coal as the primary source of electricity production.¹⁹

The promises associated with the expectation of robust and relatively cheap shale gas and high-cost but rising tight oil production have also led to a tempering of investments in renewable energy and nuclear power.²⁰ If, as this report shows, these premises and promises are indeed false, the implications are profound. It calls into question plans for LNG and crude oil exports and the benefits of the shale boom in light of the amount of drilling and capital investment that would be required, along with the environmental and health impacts associated with it. Conventional wisdom holds that the shale boom will last for decades, leaving the U.S. woefully unprepared for a painful, costly, and unexpected shock when the shale boom winds down sooner than expected. Rather than planning for a future where domestic oil and natural gas production is maintained at current or higher levels, we would be wise to harness this temporary fossil fuel bounty to quickly develop a truly sustainable energy policy—one that is based on conservation, efficiency, and a rapid transition to distributed renewable energy production.

¹⁵ Nelson Schwartz, "Boom in Energy Spurs Industry in the Rust Belt," *New York Times*, September 8, 2014, <http://nyti.ms/1qHoxXz>.

¹⁶ Jay Fitzgerald, "Pressure builds to allow US exports of crude," *Boston Globe*, September 21, 2014, <http://bit.ly/1uDI0sP>.

¹⁷ Amy Harder, "House Passes Bill Speeding Up Liquefied Natural-Gas Exports," *Wall Street Journal*, June 25, 2014, <http://on.wsj.com/1lsgKqN>.

¹⁸ Robert Blackwill and Meghan O'Sullivan, "America's Energy Edge: The Geopolitical Consequences of the Shale Revolution," *Foreign Affairs*, March/April 2014, <http://www.foreignaffairs.com/articles/140750/robert-d-blackwill-and-meghan-l-osullivan/americas-energy-edge>.

¹⁹ Isaac Arnsdorf, "Fracking Sucks Money From Wind While China Eclipses U.S.," *Bloomberg*, May 29, 2014, <http://bloom.bg/1iu9Y3m>.

²⁰ *Ibid.*