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Projections of Marginal Wells and Their Contributions to Oil and Natural Gas Supplies

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Abstract

Low volume wells yield a meaningful percentage of the crude oil and natural gas produced in the U.S. During 2003, about 29 percent of the crude oil and more than 10 percent of the natural gas was attributable to marginal wells. Moreover, more than two-thirds of the wells in the United States are marginal. The value of marginal well production simply cannot be over-stated.

Given the significance of marginal production, "first order" forecasts of recent production and well count trends were developed in order to gain insights on the future contributions from these type wells. Volumes of crude oil and natural gas [from marginal wells] are estimated to be approximately 4 Tcf_e in 2025, an increase of nearly 20 percent compared to 2003 volumes. Further, the total number of marginal natural gas wells is projected to increase by more than 160,000 to over 400,000 wells. Clearly, myriad policies and technologies must continue to advance in order to keep these wells flowing and contributing to the economic growth and energy security of the United States.

Background

A producing oil or natural gas well is considered to be "marginal" if it is producing at such a rate that it is at the limit or margin of profitability. Obviously, this rate varies and is dependent upon many factors including: operating costs, product prices, tax rates, debt service, environmental costs, and plugging and abandonment liabilities to list just a few. A well could produce at relatively high rates but still be considered marginal due to many factors. For example, one factor is high water cut which contributes to higher than normal operating costs. Marginal wells and the production therefrom are commonly referred to as stripper wells and stripper production, respectively. Throughout this paper "marginal" and "stripper" will be used interchangeably with respect to wells and production volumes.

Notwithstanding the above factors, several "formal" definitions and/or thresholds of production have been established to characterize marginal crude oil and natural gas production.[1] The Interstate Oil and Gas Compact Commission (IOGCC) defines stripper wells as wells producing 10 (or less) barrels of oil per day and no more than 60 Mcf per day of natural gas. The IOGCC does not distinguish between light and heavy oil.[*] The study described herein relied heavily on data from the IOGCC's annual surveys of marginal production and as such, the Commission's definitions were adopted for use in this forecasting endeavor.

The Interstate Oil and Gas Compact Commission has been documenting production annually from low volume wells for over 50 years. The Commission's most recent data show that marginal oil wells produced about 29 percent of Lower-48, onshore production during 2003.[2] Marginal wells meanwhile, accounted for about 11 percent of natural gas production in the contiguous states (onshore) during this same period. Production volumes, as reported by the IOGCC, were 314 million barrels and 1.5 trillion cubic feet. These volumes are up appreciably from the 24 percent (oil) and 8 percent (natural gas) reported just five years earlier. More than 390,000 marginal oil wells and 261,000 stripper gas wells were operated during 2003. Overall, the stripper oil well production rate averaged slightly more than 2 barrels of oil per day (bbl/d) while natural gas wells averaged just over 15 Mcf/d.

Introduction

Due to the relatively mature nature of U.S. crude oil and conventional natural gas resources, the country is fairly unique in that much of its [domestic] supplies are produced by low volume wells. The majority of these wells are owned, maintained, and produced by independent operators as opposed to large integrated E&P firms which operate globally. Taken individually, marginal wells are relatively insignificant. Taken in concert however, they account for a large proportion of the jobs and the corresponding economic growth associated with the petroleum industry in this country. Still another reason these wells are so important is that they serve as access to much of the remaining oil and natural gas resource. To this day, the potential remains for advanced technologies to enhance the recovery of crude oil and natural gas both residual and by-passed in discovered reservoirs. If these wells are shut-in, and subsequently plugged and abandoned, it becomes

[*] As reported in the IOGCC's annual survey of marginal wells

much more unlikely these remaining reserves will ever be produced due to the [significant] costs associated with drilling, completing, and equipping new wells.

The key to the survival of marginal oil and natural gas wells is and always has been incentive programs and improved cost-effective technologies/operational strategies. Typical operators of stripper wells do not have the means to conduct their own research, therefore federal and state funding is required to develop the new technologies needed to keep these low rate wells flowing. In keeping with the needs of smaller operators, the U.S. Department of Energy's National Energy Technology Laboratory (NETL) developed and manages an important research and development program focused at marginal well issues.[3]

In short, the NETL sponsored program -- the "Stripper Well Consortium" -- is an industry-driven group assembled to develop, demonstrate, and deploy new technologies needed to improve the production performance of natural gas and petroleum stripper wells. The Stripper Well Consortium (SWC) solicits, reviews, and selects co-funded research projects in three broad areas: reservoir remediation, wellbore clean-up, and surface system optimization. Projects are funded on an annual basis and are selected by a seven-member executive council elected from the SWC membership. The active participation and leadership provided by all sectors of the stripper well industry has helped and continues to make the consortium a success.

In order to make informed decisions regarding the long-range focus and direction of this research effort, managers require timely data on which to base their planning and to help support their portfolio of projects. Although the IOGCC's annual survey is invaluable, a "forward looking" view was required to provide key information and insights as to the trends of marginal well counts and production at a national and regional level. By knowing where the majority of stripper wells are located and most likely will be in the out years, research funding and incentive programs can be designed to assist marginal well operators in such a way that gains can be maximized. The analysis described herein provides this prospective view and is expected to benefit NETL's Stripper Well Consortium program as well as multiple other programs and/or organizations.

Methodology

Broadly, the approach employed to project crude oil and natural gas volumes and well counts was a "trend analysis" – specifically, a linear trend analysis. A series of regressions were completed using data from multiple data sources including the IOGCC, the Energy Information Administration (EIA), and others. Results of the individual regressions/ projections were then aggregated and reported at the regional and national levels.

Note – for the purpose of the forecast and as reported here, "U.S. production" refers only to Lower-48 onshore production. Obviously, due to the high cost of producing wells in an offshore setting and in Alaska, there are no stripper wells in these regions. As noted earlier, the fraction of marginal production relative to total production has been increasing with time. This tendency was fully considered in the study given that it was a trend analysis.

The forecasts generated tie directly to recent projections of oil and natural gas supply and demand for the U.S. Specifically, the Energy Information Administration's Annual Energy Outlook – With Projections to 2025[4] was utilized. Annual Energy Outlook (AEO) projections are generated at the regional level and then aggregated to a national level. See Figure 1 for the six regions comprising the contiguous states. In this study of marginal crude oil and natural gas production, the regional data were disaggregated to the state level. The approach taken was to use the historical fraction of each state's production from within a given region. State production data for oil and natural gas for years 1994-2003 were extracted from the *Natural Gas Annual*[5] and the *Petroleum Supply Annual*[6] and used in the state level calculations. Observations of these data showed that in general, most states have not produced a constant fraction of the region's production. The fraction of production has either trended slightly upward or downward, but in a linear manner. This "course" supports the use of linear regression to project this aspect of production into the future. Results of this initial regression yielded an overall production forecast for each state in each region.

With an estimate of future oil and natural gas production in hand, the next step was to forecast the volume of marginal oil/gas production on a state basis. Using IOGCC historical marginal data along with the historical total production (both on a state basis), the fraction of total production that was marginal was calculated on an annual basis. Plotting this marginal to total ratio over time showed that in most cases the ratio also followed a linear trend. As such, use of linear regression [to project forward] was again affirmed.

The next challenge was to translate the future forecasts of marginal production obtained from the first two regressions into projections of stripper well counts. To accomplish this, a regression of IOGCC historical marginal well rates was completed. Whether serendipitous or not, the majority of stripper well production rates showed a linear trend – whether increasing or decreasing – with time.

In order to generate the projections, the estimates of marginal production for all forecast years from the second regression and the estimates of average marginal rate from the third set of regressions were used to forecast marginal well counts for each product – crude oil and natural gas. The number of marginal wells was determined by dividing the marginal production volume by the average [marginal well] production rate.

Now, given that three different historical data sets showed that for all intent and purpose, a straight-line trend over the time period of 1994 to 2003 was prevalent, a high level of confidence in the use of linear extrapolations [to forecast future production volumes and well counts] was established.

The assessment/forecasting methodology can be succinctly described by the following steps:

- Acquire state historical oil and natural gas production data for years 1994-2003
- Determine fraction of regional production produced from each state for years 1994-2003
- Regress state fraction of regional production data to derive linear function in order to project fraction of regional production produced annually in a given state
- Calculate annual future production forecast for the state
- Calculate historical state annual marginal to total production ratios
- Regress state marginal to total production ratios to derive a linear function in order to project annual marginal to total production ratios
- Multiply the ratios determined in bullet 6 by production (bullet 4) to determine forecast of state marginal production.
- Generate annual average marginal production rate for historical years 1994-2003 on a state by state basis
- Regress state average marginal production rate to derive a linear function for projecting future state average stripper production rates
- Generate well count forecasts by dividing state marginal production forecast by projection of state average stripper production rate for each year of the forecast.

Figures 2 and 3 are included to illustrate state level results of the forecasts. Natural gas data for the state of Kentucky (KY) are shown. Historical state-wide natural gas volumes, both total and the quantities from marginal wells are shown in Figure 2. Forecasts of natural gas production are also shown in the figure. The data clearly indicate that nearly all the natural gas produced in KY is from marginal wells. Looking forward and as expected, a very high percentage of natural gas production will continue to be produced from low volume wells with marginal wells contributing about 90 Bcf annually in the later years of the forecast.

Figure 3 is included to show the forecast of marginal well counts (natural gas for KY). These results are the quotient of the volumes of production and flow rates expected from marginal wells. Both historical data and projections are shown in the figure. Though not evident in the illustration, the average marginal well production rate is forecast to decrease slightly. The current rate is about 13 Mcf/d with the projection of an average stripper well flow rate of approximately 11 Mcf/d in 2025.

To complete the overall forecast, state level data were aggregated to regional levels and regional data subsequently aggregated to the national level. Crude oil and natural gas production volumes and well counts were reported. These results will be discussed in more detail in an upcoming section of this paper.

Assumptions and Limitations. The methodology utilized and described herein has limitations that readers must be mindful of when using/applying the forecast results. One critical concept – one inherent to all forecasts – is that the projected volumes and quantities will mostly likely not be those that actually come to bear. The results represent a scenario which may occur if current tendencies continue into the future. The forecasting method is a "trend" analysis and nothing more. It is simply a progression of past propensities related to marginal well production and does not incorporate any major new oil or natural gas discoveries. Further, other changes in the oil and natural gas industry, which might significantly alter the relative production volumes and the results described here, are not explicitly considered.

Another important point is that the ratio of marginal to total production does not change with commodity prices, historic or projected. This is not intuitive. However, if one reviews historical product price and marginal well count data, a correlation is shown to be non existent. Figures 4 and 5 present historical and AEO projected oil and natural gas prices, and marginal well counts, respectively. The historical data show that in general, marginal well counts do not respond to the volatility of commodity prices during the ten-year historical period. This obvious lack of sensitivity in marginal well operation versus product prices further supports use of a trend analysis as opposed to a much more rigorous scheme that incorporates price changes, tax rates, O&M costs etc.

Still other assumptions that affect the results of this analysis are the assumptions inherent to the Annual Energy Outlook projections. This may not be readily apparent, but since the future production volumes used in this analysis are those reported in AEO2005, limitations and assumptions employed in that macro-economic modeling activity weigh in. Further, but importantly, the AEO oil and natural gas supply volumes are generated on a regional basis. Using a historic trend, these regional data were decomposed to a state level. The state level trends utilized in this forecast may change with each coming year of resource development and would therefore yield different results.

The IOGCC may also issue guidelines and other criteria for state agencies to use when constructing the marginal well survey. The IOGCC data were employed in this effort and any such parameters would necessarily flow down to this analysis.

Results

A forecast of marginal well count was generated for both oil and natural gas through the year 2025. The forecasts of production and well count generated by the analysis are best displayed graphically. Figure 6 shows historical oil production (total and marginal) as well as forecasts of total oil production reported by the AEO and marginal oil production as forecast in this activity. Figure 7 displays these same projection but for natural gas. As detailed earlier, the national data were generated from regional data.

Figure 6 shows that total oil production which declined about 25 percent over the last 10 years is expected to continue declining at a rate of about 1.5 percent per year over the forecast period. During this time period, the level of marginal oil production, which declined only 8 percent during the 10 year historical period, will continue to decline at a rate of about 1 percent per year. This means that the percentage of oil production which is stripper will continuously increase over time. Figure 7 shows that natural gas production, which increased about 6 percent over the 10 year historical period, will peak around 2012 and then begin a gradual decline. Marginal natural gas production, which was up about 6 percent per year over the history period, is expected to continue increasing throughout the forecast period at an annual rate of about 2.5 percent per year. This also signifies that the percentage of natural gas production that is marginal will continue to increase.

Well counts (marginal wells) were also estimated in this analysis. These forecasts are shown in Figure 8. There are no major surprises in this chart as the fairly well defined linear trends of the last 10 years are continued in the projections generated by the model. The marginal oil well count will decrease and the marginal natural gas well count will increase. Overall, the total number of marginal wells is expected to increase about 9 percent by 2025.

Examples of a regional forecast are provided in Figure 9 and Figure 10, production and well counts, respectively. Results for all six regions, in addition to the national projections are discussed in more detail in the activity's final report.[7] For this short paper however, regional marginal production and well count results are summarized in Tables 1 and 2.

More detailed information and data are presented in the final report on a 5-year basis. Forecasts for five time periods are shown in addition to two historical timeframes. Table 3 is included as an illustration of said data. Along with the requisite values of total production, marginal production, and marginal well counts; values are also supplied for percent of total production which is marginal and for the average marginal well production rate.

As a means of validating the forecasting methodology used to generate the results described in this paper, a history match was performed in order to estimate marginal production and marginal well count for years 2002 and 2003. These estimates were then compared to the actual historical results. The national results turned out very close with the production matching historical production within 2.0% for oil and 4.7% for natural gas each year on average. The well count was within 3.3% each year on average for both oil and natural gas. These results provided a high degree of confidence in the short term national projection generated by the model. Only time will tell as to the validity of the national results over longer periods of time.

The major accomplishments of the work described in this paper may be summarized as follows. A method for predicting future marginal oil and natural gas production as well as future marginal well counts has been developed. The method is a simple "trend analysis" which relies on linear regression of historical data. The method is directly tied to historical data from the IOGCC annual publication *Marginal Oil and Gas: Fuel for Economic Growth* and future forecasts of oil and natural gas production from the EIA publication *The Annual Energy Outlook (AEO)*. An updated forecast of marginal production and well count could easily be generated each year as annual updates are made available to these data sources.

Conclusions

Via examination of the high level results presented here, as well as the more detailed results of the analysis, the following can be concluded:

- The percentage of both oil and natural gas production from stripper wells will continue to increase – According to model results, the percentage of oil production which is stripper will increase from about 28 percent of production today to about 32 percent or 243 MMbbls in 2025. Marginal natural gas wells are forecast to produce over 17 percent or 2.5 Tcf of total natural gas production in 2025 up significantly from the 11 percent of production today. Combined, total production from stripper wells is expected to be approximately 4 Tcf_e in 2025.

- The relative importance of marginal, natural gas wells will increase while that of marginal, oil wells will decrease over time – At the start of 2004 there were about 393,000 marginal oil wells and about 260,00 marginal natural gas wells. According to the forecasts generated, the number of marginal oil wells will continue to steadily decline due to increasing abandonments while the number of marginal natural gas wells will steadily increase due to increased natural gas well drilling. The number of natural gas stripper wells is expected to surpass the number of oil stripper wells in the 2011 timeframe. By 2025 the number of stripper wells (natural gas) will be more than one and a half times the number of stripper oil wells. This is an artifact of a mature oil province, which has been in a steady decline for several decades.

- Focus of marginal oil wells to shift more and more to the central and western regions over time – Currently, about 40% of the marginal oil wells are located in the Northeast and Gulf Coast regions. By 2025 the model forecasts that only 21 percent of marginal oil wells will be located in these two regions. The four western supply regions Mid-continent, Southwest, Rocky Mountain, and West coast will all increase their relative fraction of the total number of stripper wells with the largest increases coming in the Southwest (Permian basin) and the Mid-continent regions. The Southwest region could increase its share from 26 percent to 32 percent of oil stripper wells in the Lower-48 states while the Mid-continent region could show gains moving from 23 percent to 29 percent. All of the

regions are forecast to experience decreases in the absolute number of marginal oil wells with the exception of the Rocky Mountain region in which the number of stripper wells is projected to increase about 12 percent over the next 20 years.

- Expect significant increases in marginal natural gas wells in Rocky Mountain region – At this time, the Northeast region is home to about 55 percent of all Lower-48 stripper wells (natural gas). The west coast has a negligible number of natural gas stripper wells; the Permian basin holds about 4 percent of all natural gas strippers while the remaining three regions each contain about 13.5 percent of the Lower-48 natural gas stripper wells. According to the model, by 2025 the Rocky Mountain region will have about 21 percent of all natural gas stripper wells. This can be attributed to a large amount of drilling for unconventional natural gas currently underway and expected in this region. The model is forecasting over a three fold increase in the number of marginal natural gas wells in this region. The remaining regions will all have a reduced share of the total number of natural gas stripper wells in the U.S. The Northeast region can be expected to have a lesser share of stripper wells with the number corresponding to about 53 percent of the total share. In 2025 it is expected that 74 percent of all natural gas stripper wells will be found in either the Northeast or Rocky Mountain regions. With the exception of the West Coast region, all of the natural gas supply regions are expected to experience relatively large increases in the number of marginal wells during the next 20 years.

All objectives set forth at the onset of this effort have been met. [Marginal] production volumes and well counts on a regional basis have been estimated for the forthcoming two decades. These data have been provided to officials of NETL's Stripper Well Program in order that future RD&D be designed to address the most anticipated and significant issues related to low volume oil and natural gas wells. These data, combined with other drilling and production operations information provide the core for implementing an effective technology development program which includes tailored operational strategies.

Any related and potential future efforts could be directed towards more detailed analysis of marginal natural gas production in the Northeast and Rocky Mountain regions. These two areas appear to be in the greatest state of flux as far as natural gas production is concerned over the past several years. Improvements in forecast results could be made to develop more detailed insights of when and where drilling is likely to occur in these regions. Research could then be focused in a commensurate manner.

Depending on the need to "balance" the technology program, there may be a desire to focus attention on marginal wells in greatest danger of abandonment -- stripper oil wells in the Northeast and Gulf Coast regions. It appears that stripper oil wells in the Northeast region are especially at risk because most of the [marginal] wells in this region produce at a fraction of a barrel of oil per day.

Acknowledgements

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Nomenclature

Bbls	barrels
d	day
IOGCC	Interstate Oil and Gas Compact Commission
KY	Kentucky
Mcf	thousand standard cubic feet
subscript **e**	equivalent
Tcf	trillion standard cubic feet

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Figures

Figure 1. Oil and Gas Supply Module Regions (AEO/EIA).

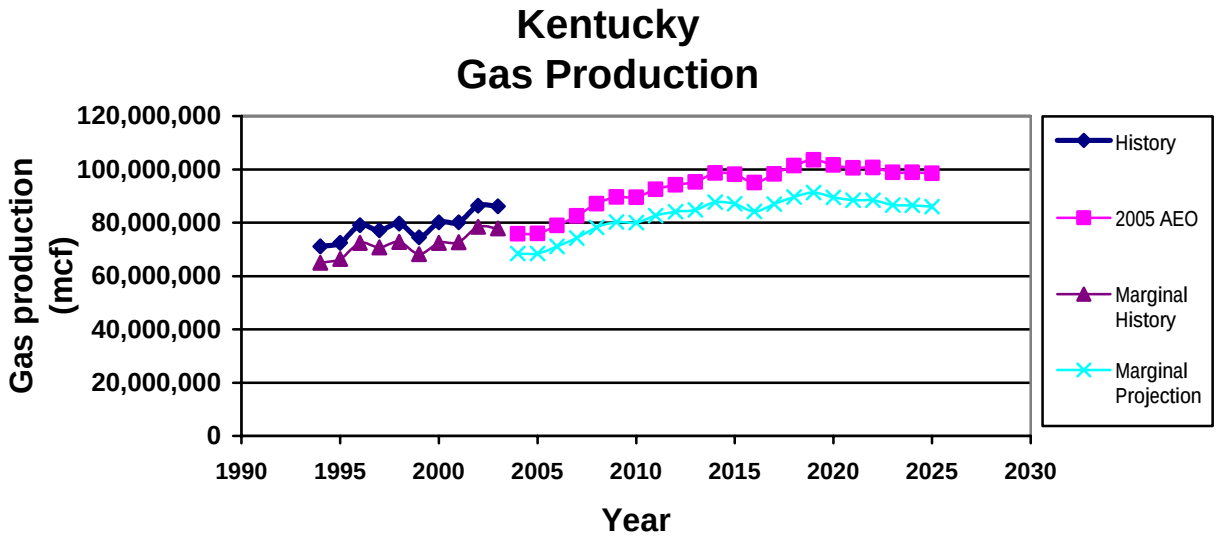

Figure 2. Example of state level total and marginal production volumes – historical and forecast.

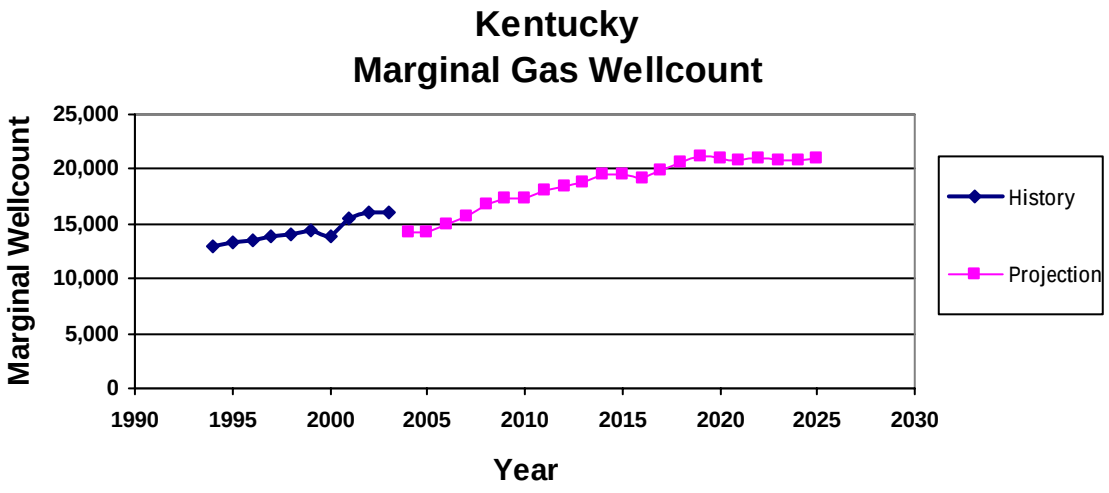

Figure 3. Example of state level stripper well counts – historical and forecast.

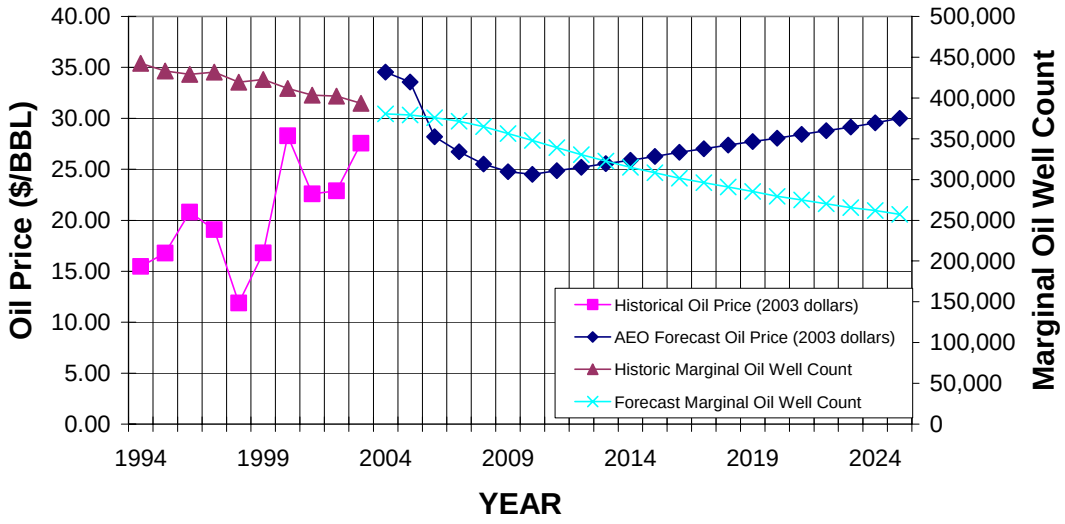

Figure 4. Commodity (oil) price versus stripper well count.

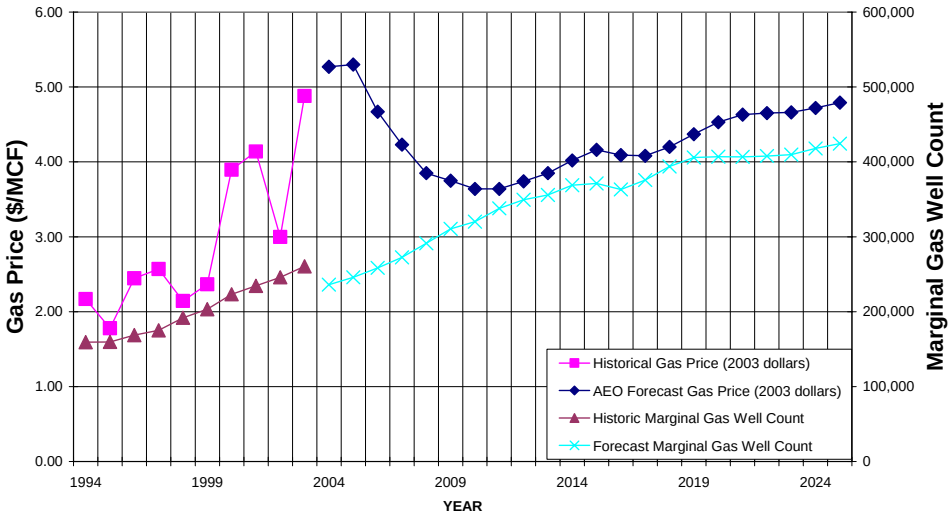

Figure 5. Commodity (natural gas) price versus stripper well count.

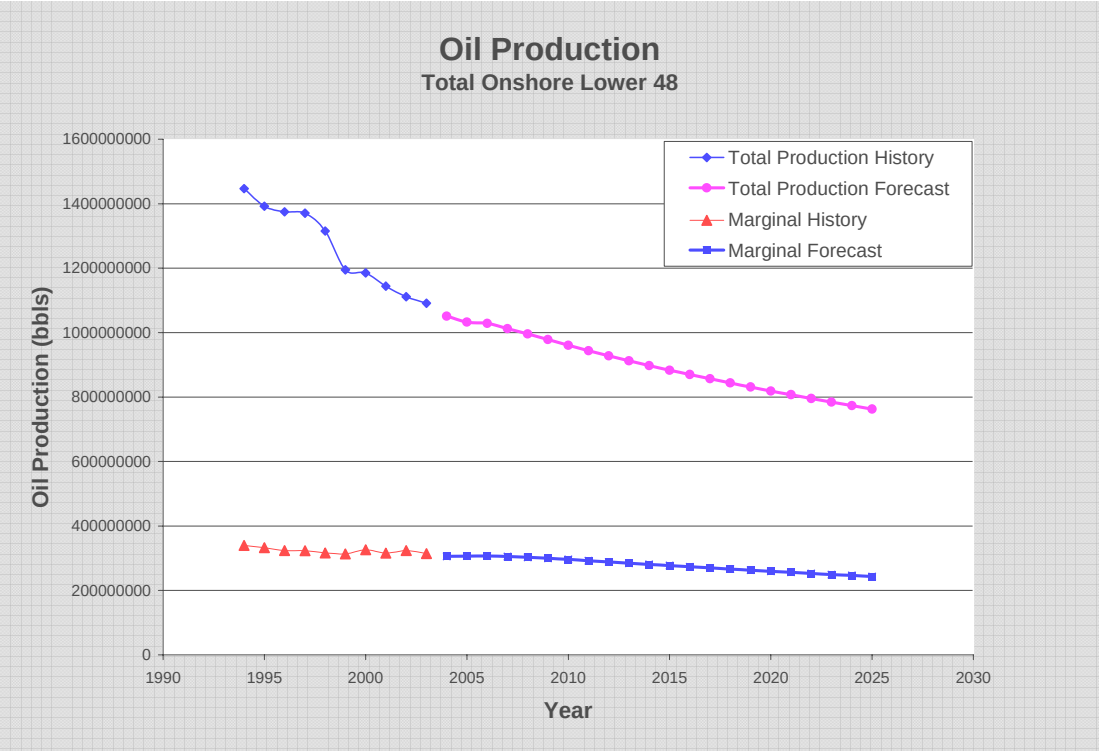

Figure 6. Forecast of crude oil production from marginal wells.

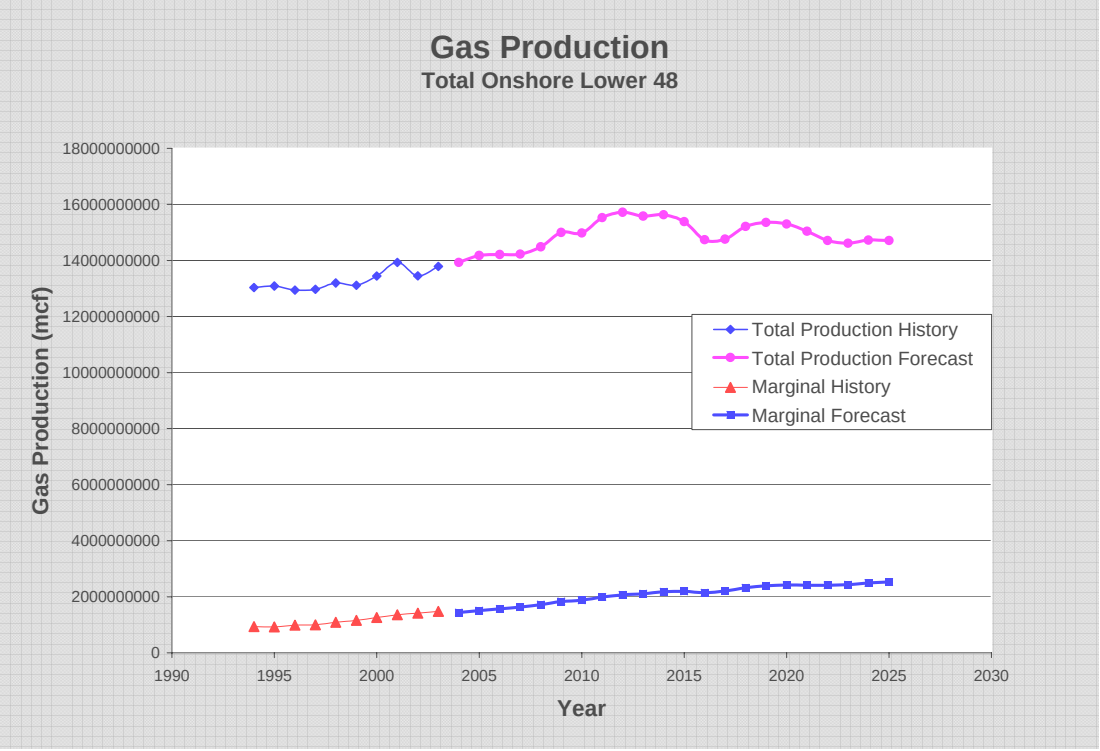

Figure 7. Forecast of natural gas production from marginal wells.

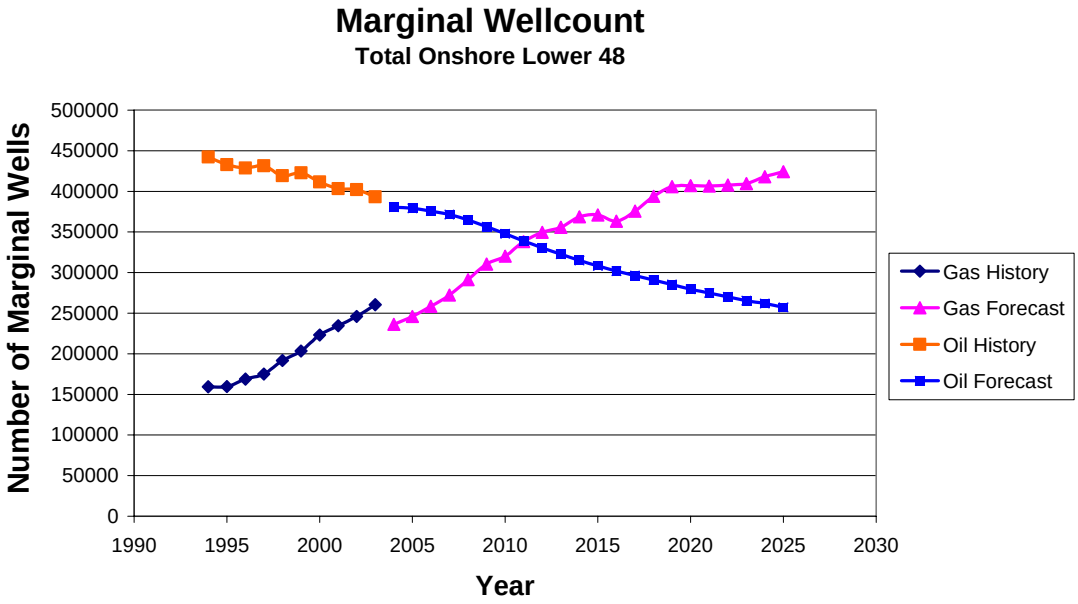

Figure 8. Forecast of marginal oil and natural gas wells.

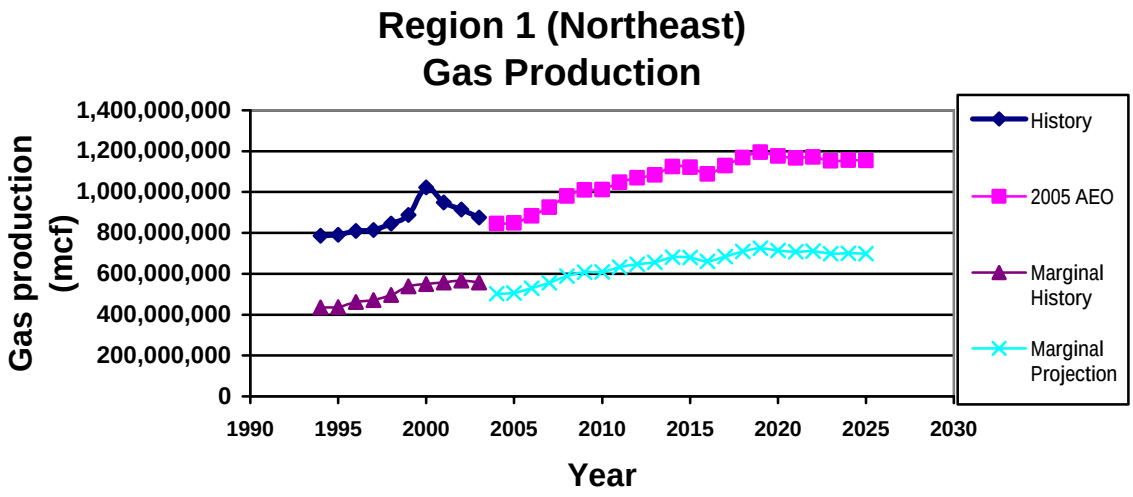

Figure 9. Regional forecast of production from marginal wells-included as an illustration.

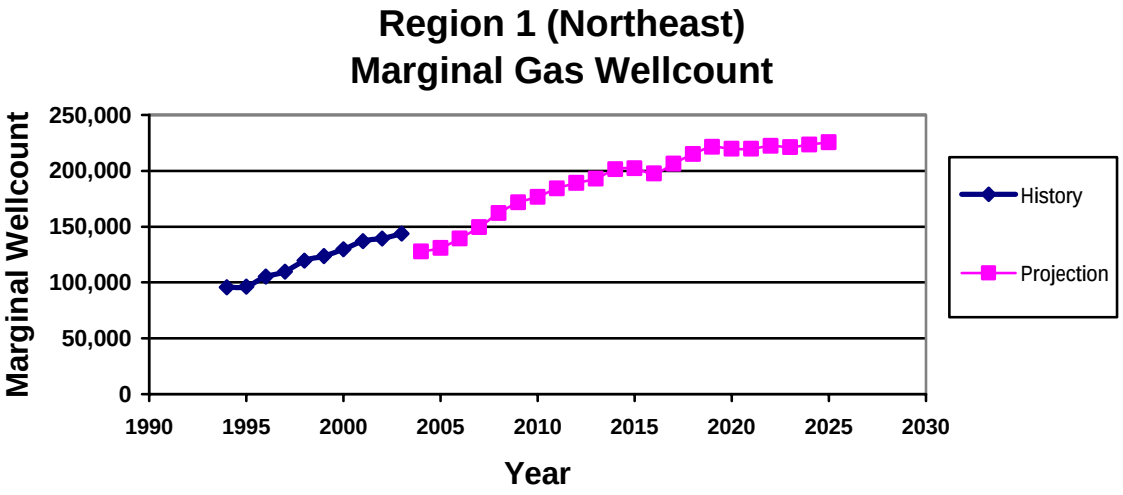

Figure 10. Regional forecast of marginal wells – included as an illustration.

Tables

Table 1. Regional forecasts of marginal well counts.

	Marginal Oil Well Count			Marginal Natural Gas Well Count		
	2005	2015	2025	2005	2015	2025
Northeast	99,492	54,230	36,151	130,938	202,274	225,671
Gulf Coast	49,369	27,693	17,721	34,769	41,136	43,936
Mid-Continent	92,512	86,209	74,347	36,623	49,992	48,309
Southwest	95,380	91,711	82,536	12,167	18,264	18,536
Rocky Mountain	19,069	26,575	25,161	31,183	59,279	87,717
West Coast	23,303	21,849	21,305	303	169	69
Total U.S Lower 48	379,125	308,267	257,221	245,984	371,115	424,238

Table 2. Regional forecasts of crude oil and natural gas production from stripper wells.

	Marginal Oil Production (Mbbls)			Marginal Natural Gas Production (BCF)		
	2005	2015	2025	2005	2015	2025
Northeast	26,156	15,464	11,108	506	680	699
Gulf Coast	50,351	33,454	23,975	247	333	389
Mid-Continent	77,575	74,621	66,419	350	437	408
Southwest	99,256	95,827	86,687	103	160	168
Rocky Mountain	20,131	28,910	28,627	298	582	867
West Coast	32,567	28,711	26,218	2	1	0
Total U.S Lower 48	306,036	276,987	243,034	1,507	2,193	2,531

Table 3. Regional forecasting data, Northeast Region, natural gas.

Year	1995	2000	2005	2010	2015	2020	2025
Total Gas Production (MMcf)	790,388	1,022,004	848,000	1,011,000	1,122,000	1,176,000	1,154,000
Marginal Gas Production (MMcf)	436,887	548,901	506,364	609,335	679,866	713,614	698,543
Per cent Marginal Production	55.28	53.71	59.71	60.27	60.59	60.68	60.53
Number of Marginal Gas Wells	95,619	129,905	130,938	176,774	202,274	219,744	225,671
Average Marginal Well Rate (Mcf/day)	12.52	11.58	10.60	9.44	9.21	8.90	8.48

Note: significant digits not reconciled in the data shown.