energy&fuels

Generalized Extreme Value Statistics, Physical Scaling, and Forecasts of Gas Production in the Barnett Shale

Tadeusz W. Patzek*, Wardana Saputra, Wissem Kirati and Michael Marder

Cite this: *Energy Fuels* 2019, 33, 12, 12154-12169
Publication Date: October 22, 2019
https://doi.org/10.1021/acs.energyfuels.9b01385

SUBJECTS Lipids, Deformation, Natural resources, Shale Mathematical methods

Abstract

We develop a new method of predicting fieldwide gas or oil production from unconventional reservoirs, using the Barnett shale as an illustration. First, we divide the qualifying 13 141 horizontal gas wells in the Barnett into six static samples in which reservoir quality and completion technologies are similar. These

statistical well prototypes are conditioned by well attrition, hydrofracture deterioration, pressure interference, well interference, progress in technology, and so forth. So far, there has been no physical scaling. Third, we fit the parameters of our physical scaling model to the statistical well prototypes and obtain their smooth extrapolations to 30 years on production. At late times, we add radial inflow of gas external to the stimulated reservoir volumes of the mean wells. Fourth, we calculate the number of potential wells per square mile of each Barnett county and schedule future drilling programs. We then stack up the extended well prototypes to obtain the plausible forecasts of gas production in the Barnett until the year 2034. We predict that the six Barnett counties will ultimately produce 24.5 trillion standard cubic feet (Tscf) of gas from the existing wells. On energy equivalent basis, in this “do nothing” scenario, these counties will produce 4.2 billion barrels of oil equivalent, making it one of the top producers of fuel for the US. Finally, we consider a possible addition of 4.5 Tscf from the future 3570 surviving wells or 6800 new wells drilled between 2019 and 2028. On the average, only 1/2 of the current Barnett wells will survive beyond 15 years on production.

1. Significance Statement

Figure 1a provides the history of electricity generation in the US between 1949 and 2018. In 2018, coal- and natural gas-fired power stations provided 62% of electricity, nuclear power stations, 21%, while water turbines, wind turbines, and other renewables supplied the remaining 18% of electricity. Figure 1b charts the number of days per year the US was powered by each major source of electricity. In 2018, for example, natural gas provided 113 days of US electricity.

Figure 1

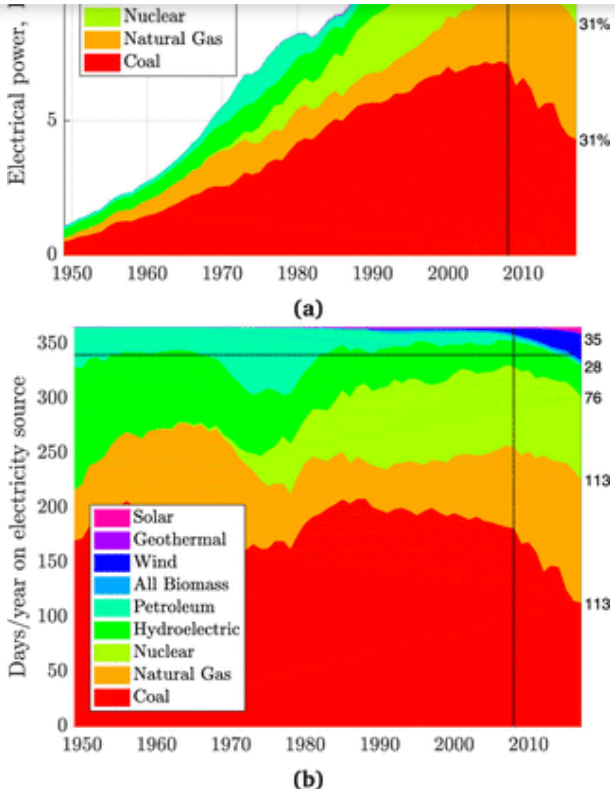

Figure 1. Production of electricity in the US, 1949–2018. (a) In 2018, baseload power stations produced 90% of electricity and 31% generated from natural gas. Wind and other renewables supplied 10% of electricity. The vertical line denotes the onset of the 2008 financial crisis. (b) Days per year the US was powered by each source of electricity. In 2018, coal, oil, natural gas, and uranium powered US electricity between Jan 1 and Oct 29, and hydropower, until Nov 26. All renewables combined powered US only through December. This picture has not changed substantially over the last 70 years; see the dotted horizontal line. Source: US DOE EIA, accessed 1/30/2019.

In 2018, 55% of natural gas consumed in the US was produced from shales, and 31% of electricity was produced from natural gas. Given the vital importance of natural gas to the US economy, it is of interest to assess how well the past forecasts of production of gas from shale plays have aged.

Early on, Kuuskraa et al. 1998 claimed: "...the Barnett shale might hold 10 tcf of technically

(4−7) Some of the original model restrictions on estimated ultimate recovery (EUR) were subsequently relaxed in refs,(8−10) resulting in the Barnett and Fayetteville shale gas production outlooks that were overly optimistic.

In this article, we introduce a rigorous, robust method of statistical and physical modeling of production from thousands of shale wells and show how to obtain detailed estimates of future production in a manner that is resistant to bias. Investors and policy-makers should beware of assuming that the shale gas boom will last for many decades to come.

2. Introduction

The US Energy Information Administration (EIA) estimates that in 2017, about 16.76 trillion standard cubic feet (Tscf) of dry natural gas was produced from shale resources in the United States. This was about 60% of the total US dry natural gas production in 2017.

The net gas withdrawals from the horizontal wells in the 12 plays shown in Figure 2 were 15.4 Tscf in 2017. The difference of 1.36 Tscf is caused by our omission of smaller plays responsible for ~1 Tscf in 2017 and exclusion of vertical wells. In any event, US shales produced over 50% of all US gas in 2017. Cumulatively, this level of shale gas production was achieved with the 81 000 horizontal wells, as shown in Figure 3.

Figure 2