



# **Improved USGS Methodology for Assessing Continuous Petroleum Resources Using Analogs**

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# Improved USGS Methodology for Assessing Continuous Petroleum Resources Using Analog

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This talk was originally presented at the Third Symposium on Resource Assessment Methodologies in Canmore, Alberta, on September 17, 2010.

# Current USGS Assessment Methodology for Continuous Resources



## Current USGS Methodology

- Based on productivities of cells
  - Cells are roughly the size of the drainage area of a well
- Well productivities determined by decline-curve analysis
- Estimates of numbers of cells based on
  - Area of assessment unit (AU)
  - Percent of area already tested
  - Area of a cell



The current USGS methodology uses well production data, as opposed to volumetric calculations based on area, thickness, porosity, and hydrocarbon saturation.

# Issues Relating to Current Assessment Methodology



## Need for Improved Methodology

- Frontier assessment units (AUs)
  - No or little previous production
  - Little information about success ratios or estimated ultimate recoveries (EURs) of wells
  - Possibility of zero potential
- Better assessment of non-frontier AUs



There is need to be able to make assessments for areas that are data-poor. These changes will also lead to improved assessments for areas that are data-rich.

## Realism

- Well productivities (EURs) connect assessments to reality
  - No “pie in the sky” promoter views of what “might” be available
  - No Lake Wobegon effect
- Much more production data available now compared to 30 years ago
  - Many more wells with longer producing histories
  - Many more plays



The “Lake Wobegon” effect is where all the wells are better than average.



## Geologic and Engineering Models

- Understanding of geologic and engineering controls on productivity not as well refined as for conventional petroleum
- Still very hard to estimate ahead of drilling
- Great improvements in last decade
  - Lots of models giving partial explanations of controls on productivity



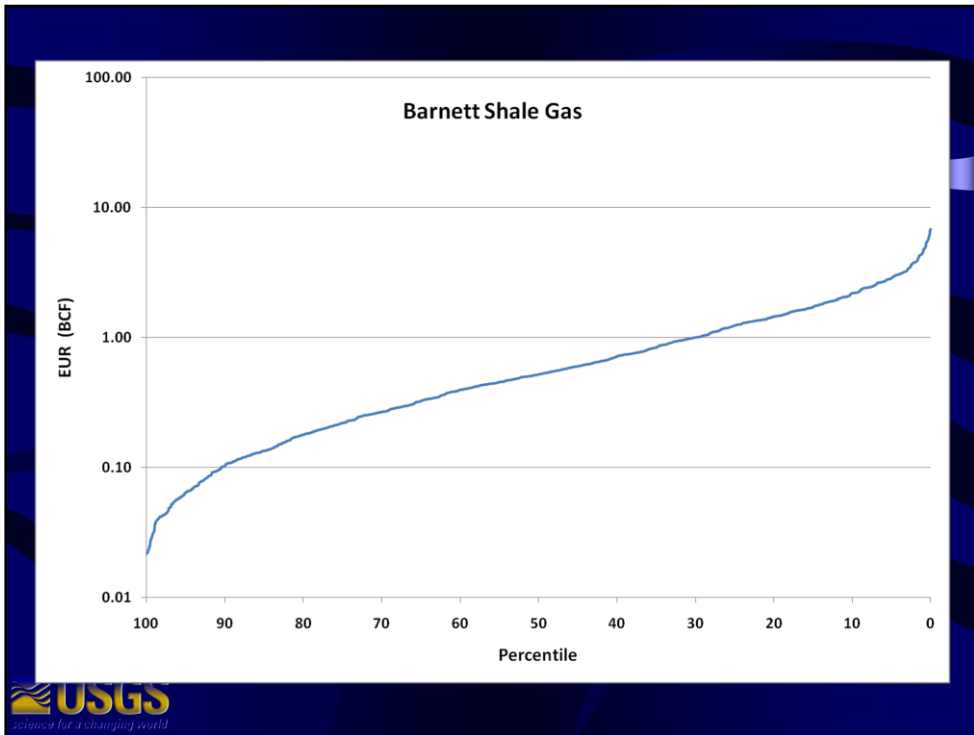
The improved methodology is not tied to specific geologic and engineering models, but is robust enough to take into account improvements in geologic and engineering understanding.

## Historical Information

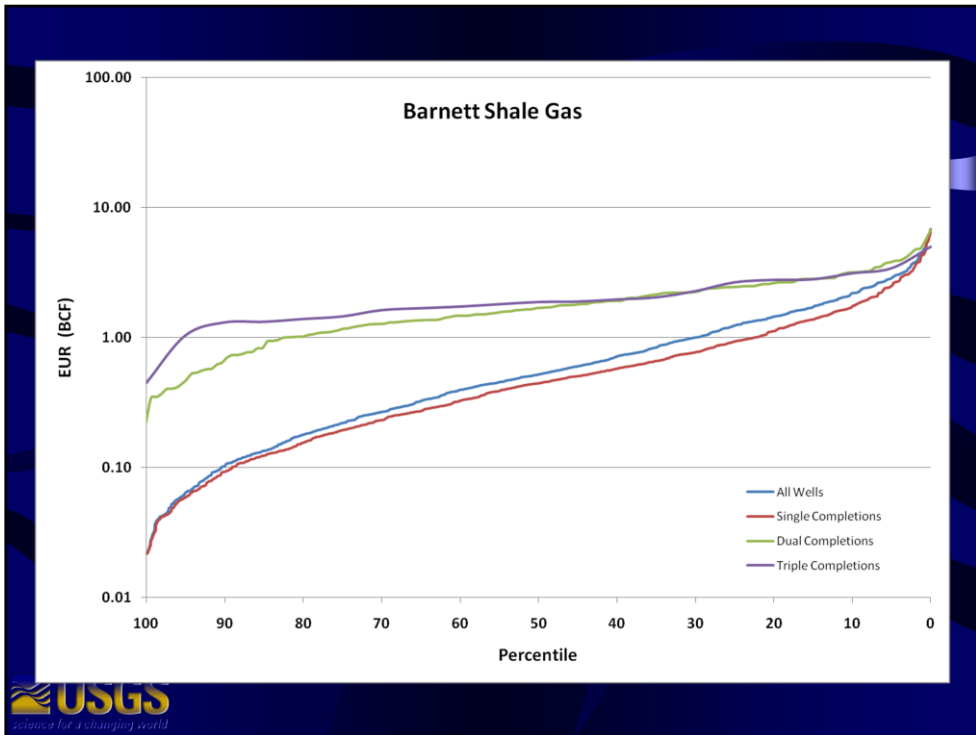
- Complex patterns
  - For example, trends in EUR with time
- Not as “well behaved” as some classic conventional data sets
  - Discovery process models less applicable
- Multiple trends going on at once
  - Analysis and interpretation needed



Historical production data from data-rich areas show complex patterns that cannot be interpreted by simple models. Instead, significant effort is commonly required to interpret the data trends.



This graph presents the estimated ultimate recovery (EUR) for 1,417 vertical wells in the Barnett Shale as of 2003. It shows the distribution of EURs for those wells with an EUR of at least 0.02 billion cubic feet (BCF). The percentiles indicate what percent of the wells have an EUR of at least the indicated amount. Note that the range of EURs is greater than two orders of magnitude.



This graph adds lines for those wells used in the preceding graph with single completions (1,240), dual completions (156), and triple completions (21).

## Sweet and Non-sweet

- Studies of some continuous deposits suggest that the productivities within a continuous deposit are a mixture of two populations
  - Most clearly seen in some tight gas sands
  - Not all deposits show this
- How do you define sweet?
  - Are sweet spots just the high end of some distribution, or are they evidence of a mixture?



The spatial distribution of well productivities is not well understood, but in many cases the highly productive wells seem to be concentrated spatially in sweet spots.

## EUR Distribution

- The overriding methodological factor is the effect of thousands of cells/wells on the EUR distribution
- Effect is that the EUR distribution “collapses” around the mean
- Old methodology acts as if the mean of the EUR distribution was known exactly



When assessment models aggregate thousands (or tens of thousands) of EURs from an EUR distribution, the result is very close to merely multiplying the number of cells by the mean EUR. Thus the assessment model acts as if the mean were known exactly. This underestimates the uncertainty in the result, especially for frontier AUs where the mean EUR is very uncertain.

# Improved Methodology for Assessing Continuous Resources



## Wells Versus Cells

- Older methodology used cells
  - Cells were theoretical concepts, not something actually mapped
  - Cell size was based on average drainage area, so as to more easily use well-based calculations of EUR
- New methodology uses well data directly
  - Estimated uncertainty about average drainage area



This change leads to less confusion about wells versus cells.



# Risk

- Well risk
  - Success ratio within potentially productive area
  - Explicitly estimated in new methodology
- Area risk
  - How large is potentially productive area?
- AU risk
  - Risk of no productive areas anywhere in AU



Risk in the new methodology is subdivided into three categories: well risk, area risk, and assessment unit (AU) risk.

## Sweet Versus Non-sweet Spots

- Old methodology treated non-sweet spots as having negligible potential
- New methodology offers option:
  - One population with one success ratio and one EUR distribution (100% sweet spots)
  - Two populations with separate success ratios and EUR distributions (< 100% sweet spots)

## EUR Distribution

- Old methodology used a distribution of EURs across the AU
  - Results dependent almost entirely on the mean
- New methodology directly estimates uncertainty of the mean



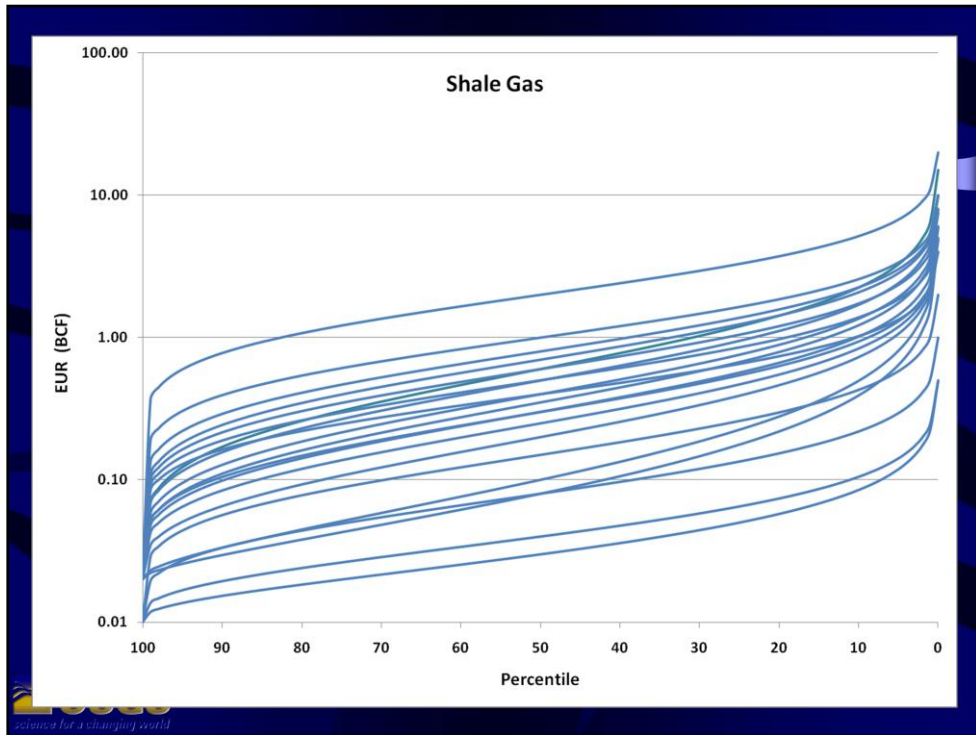
This makes the improved methodology much more applicable to frontier areas.

## EUR Analog Sets

- For this presentation, preliminary analog sets were built based on the USGS estimates of future EUR distribution for 100+ AUs in the United States.



Of the 100+ AUs for continuous oil and gas resources, 21 shale-gas AUs will be used for the example in the following graphs.



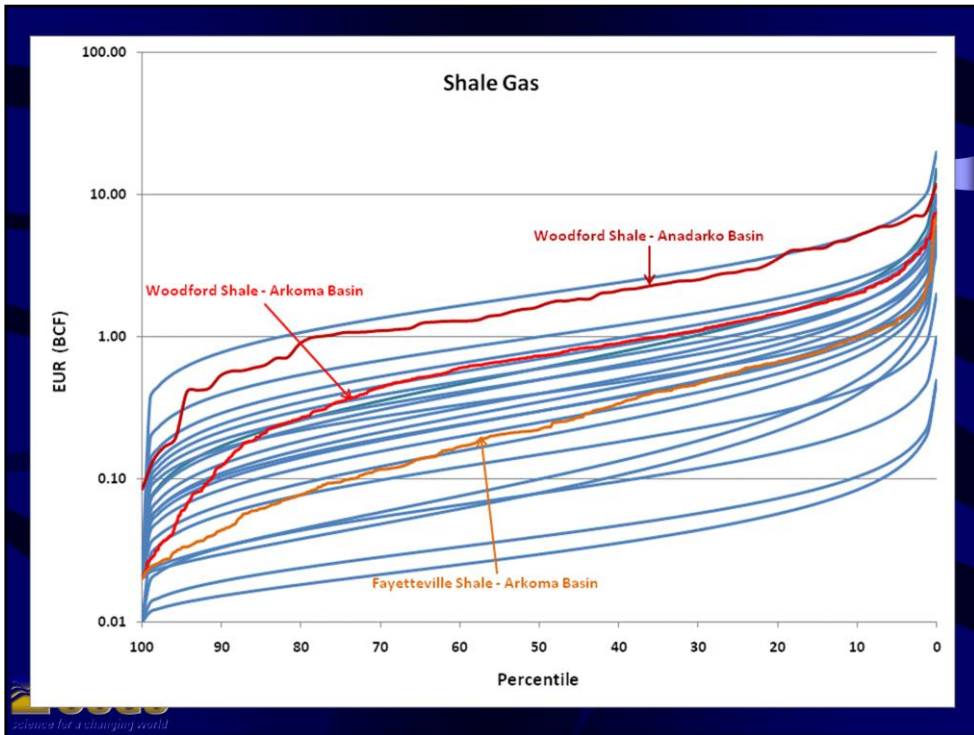
This graph shows 21 shale-gas EUR distributions, based on USGS assessments of undiscovered shale-gas resources. Each distribution is a truncated shifted lognormal, and thus is a smooth curve. The graph thus presents the “distribution of the distributions.” Each distribution is a USGS estimate of the EUR distribution for undrilled productive cells of a particular assessment unit. This graph is termed a “spaghetti plot,” which shows how EUR distributions can vary for different shale-gas assessment units. The overall area defined by the variation in EUR distributions is termed “the cloud.”

## First Generation Analog Set

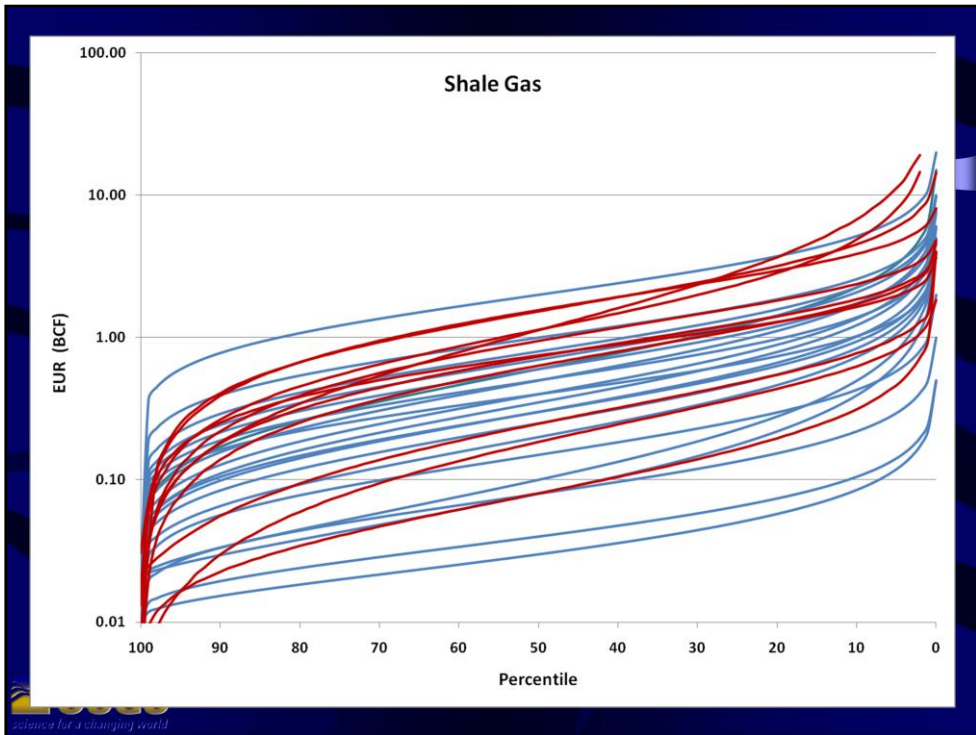
- Good approximation of full EUR distribution
  - Estimates of future EUR distribution were always close to EUR distribution of previously drilled wells
  - Effect of earlier (learning curve) wells minimized
  - Effect of geological differences in undrilled areas included



Defining the cloud by using USGS estimates of EUR distributions of undrilled cells gives a good approximation of the range of distributions. Assessments have been conducted over the last decade in a wide variety of reservoirs using a variety of completion practices, and the present sample captures much of the range of distributions based on current technology.

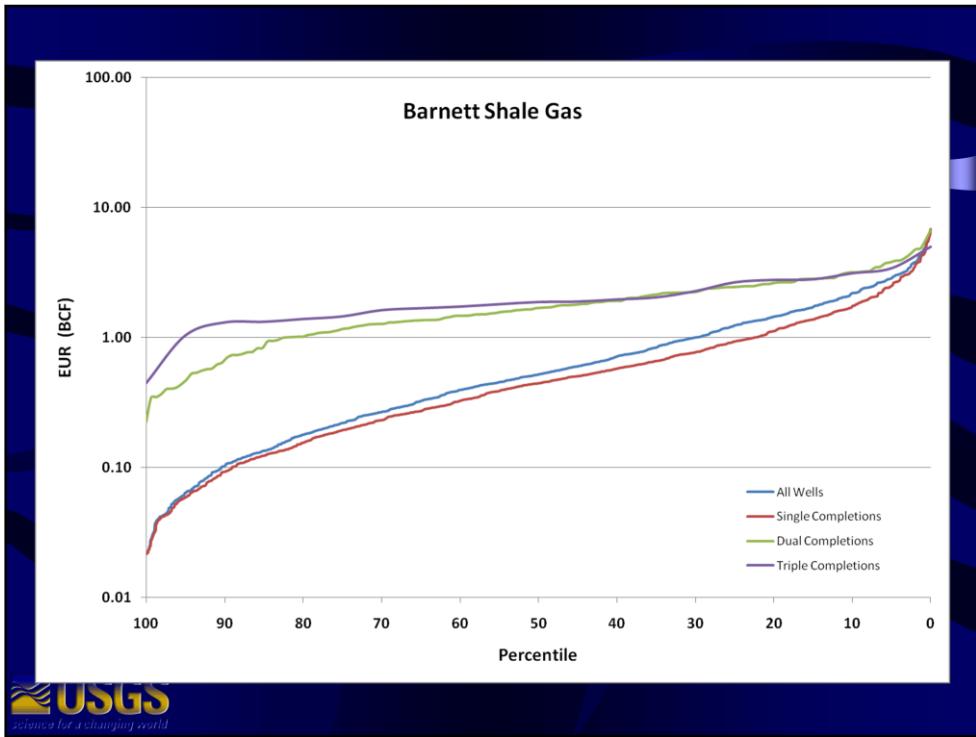


This graph adds the EUR distributions for three recent USGS sets of shale-gas wells, plotted against the cloud shown previously, to put the three distributions in context. The three additional curves are not smooth because they are based on actual well data and not on fitted distributions.

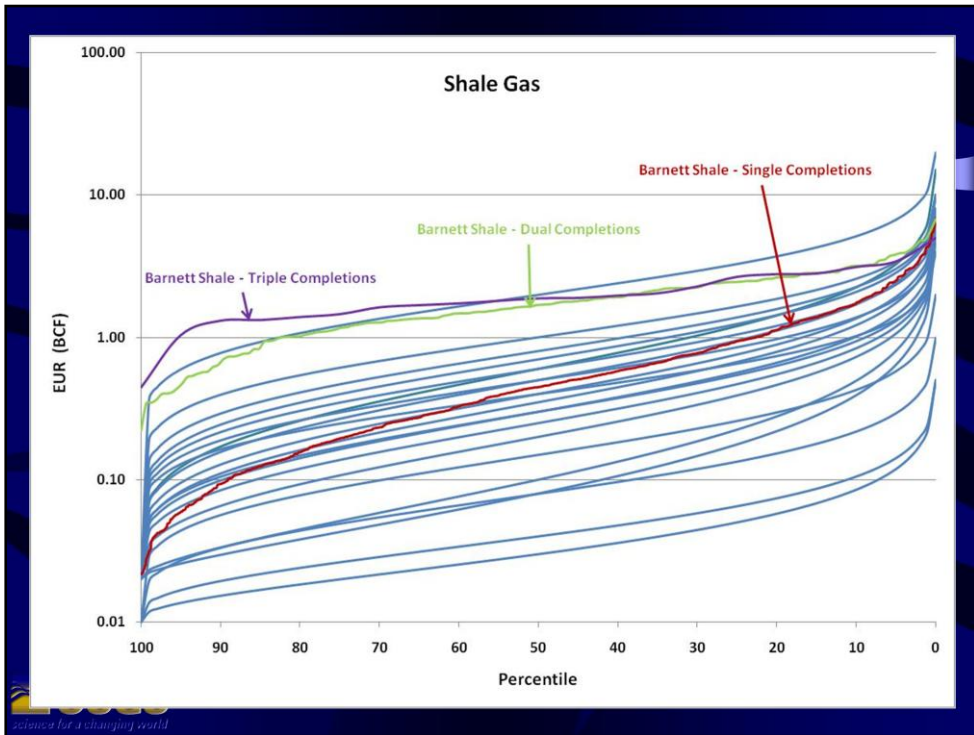


In this graph, the EUR distributions for 11 sets of shale-gas wells are plotted against the cloud to put them into context. These red curves are smooth because the data have been fitted to distributions.





This is a repeat of the graph shown on a previous slide.



The data from the previous graph are now plotted against the cloud to put them in context.

## Improving EUR Analog Sets

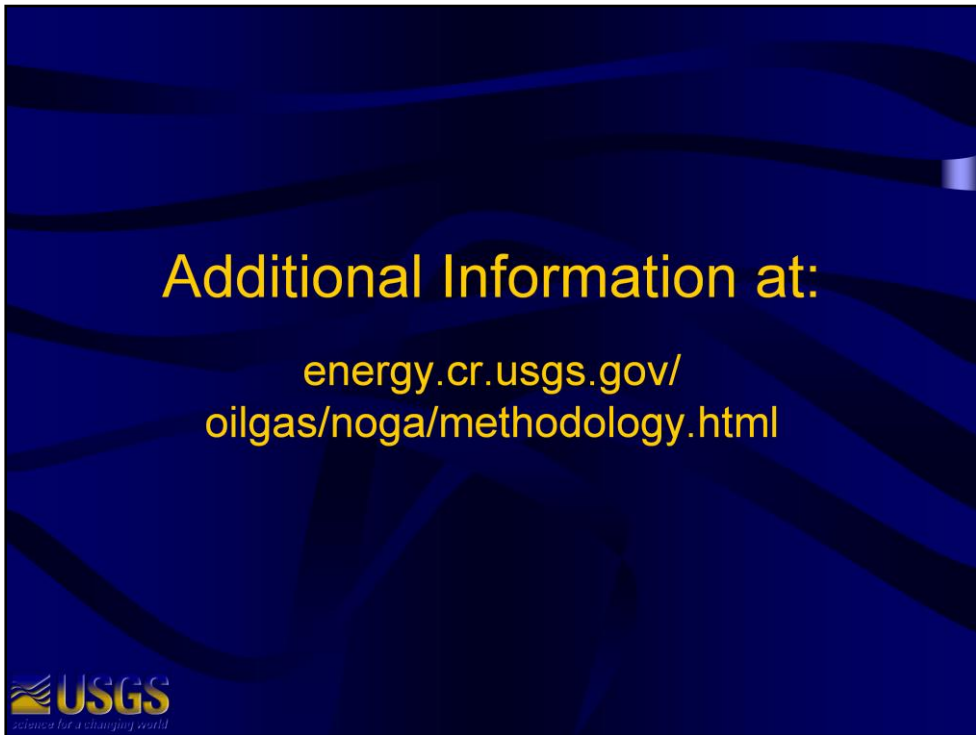
- Use same minimum
- Include both drilled and undrilled populations
- Use empirical distributions rather than lognormal
- Separate vertical versus horizontal wells
- Separate sweet versus non-sweet distributions



Although these graphs presented a reasonable first approximation for the range of variation in EUR distribution, that approximation can be better refined by the ways listed here.

## Future Work

- Develop analog databases
- Study AU and areal risk
- Study effects of spatial patterns
- Study sweet/non-sweet mixture



This website has links to references concerning the new USGS methodology, as well as references concerning previous methodologies.