Annual Energy Outlook 2018

Modeling updates in oil, natural gas, & liquid fuels

For

Oil and Gas Supply, Natural Gas Markets, & Liquid Fuels Markets Working Group

July 26, 2017 | Washington, DC [*http://www.eia.gov/forecasts/aeo/workinggroup/*](http://www.eia.gov/forecasts/aeo/workinggroup/)

By

Office of Petroleum, Natural Gas, & Biofuels Analysis

WORKING GROUP PRESENTATION FOR DISCUSSION PURPOSES
DO NOT QUOTE OR CITE AS RESULTS ARE SUBJECT TO CHANGE

Agenda

- Introductions & *AEO2018* overview (2:00-2:10)
- Liquid fuels markets (2:10-2:40)
  - World oil prices
  - Petroleum and biofuel updates
- Natural gas markets (2:40-3:15)
  - New model NGMM
    - Design: granularity, bi-directional flows
    - Improvements: prices, Mexico, LNG
- Oil & gas supply (3:15-3:45)
  - EURs and TRRs
  - Changes to accommodate new NGMM model
  - NGPL and API gravity characteristics
  - Canada representation
  - Supply response
- Wrap-up (3:45-4:00)

Office of Petroleum, Gas, and Biofuels Analysis

Lead modelers:

- Liquid Fuels Markets Module (LFMM)
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- Natural Gas Markets Module (NGMM)
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Biofuels & Emerging Technologies Team	**Exploration & Production Team**	**Liquid Fuels Markets Team**	**Natural Gas Markets Team**
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			Upchurch, Jason
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The AEO2018 is a “full” report and will include:

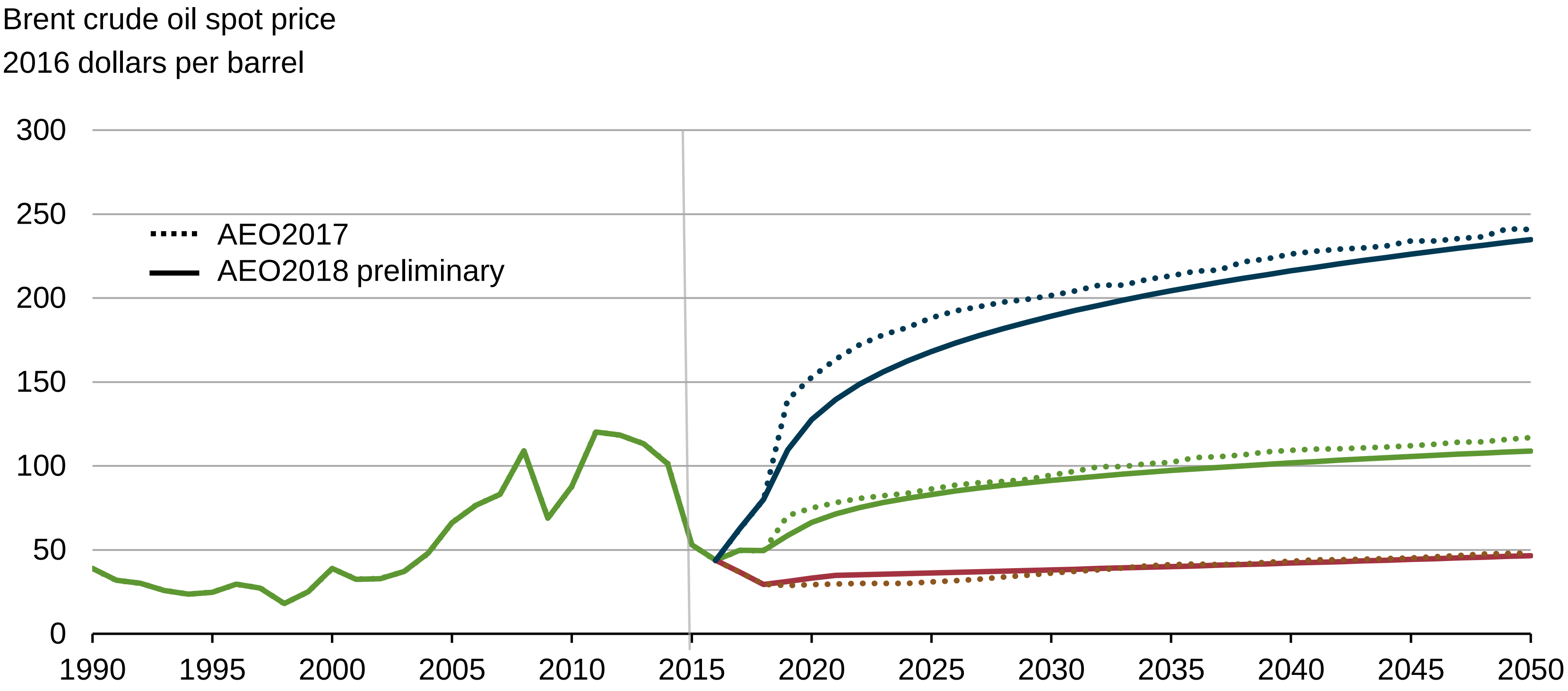
- AEO standard cases
  - Reference price case (with or without Clean Power Plan (CPP)?)
  - High and low price cases
  - High and low economic cases
  - High and low resource and technology cases
- Additional AEO side cases will be included because this is a “full” AEO year
  - Suggestions?
- Charts and tables will present projections to 2050
- Report structure will include the annotated slides and Issues in Focus articles

Liquid Fuels Markets
&
world oil prices

Discussion topics

- Lower World Oil Price compared to AEO 2017
- General crude oil and petroleum product model updates
- Reduced sulfur specification for marine bunker fuel in 2020
- Revised existing and planned biofuel production capacity and select biofuel feedstock supply curves

Crude oil price lower for AEO2018



Source: EIA, Annual Energy Outlook 2017 and preliminary Annual Energy Outlook 2018

Lower World Oil Price compared with AEO 2017

- The outlook for global liquids supply is relatively unchanged from last year, with slightly higher OPEC production largely offset by slightly lower non-OPEC production.

- Expectations for global liquids demand are lower compared with AEO 2017, with lower GDP growth in OECD and non-OECD contributing to the reduced outlook for demand.

General crude oil and petroleum product model updates

- Import and export levels of petroleum products better reflect global and domestic demand trends
- Availability and price of international crude oils are more aligned with the global refinery complex
- Octane rating for gasoline better incorporates demands for premium and mid-grades
- Distribution and marketing costs from the refinery to end-users were updated for all petroleum products
- Expected results include a reduced diesel-gasoline price spread and higher refinery utilization throughout the projection

General crude oil and petroleum product model updates (cont'd)

- Existing US refinery capacity updated using EIA's Petroleum Supply Annual (PSA)
- Existing Canadian and Caribbean refinery capacity updated using Oil and Gas Journal
- U.S. crude oil pipeline capacities updated
  - Dakota Access pipeline will be included in the model starting in 2017
  - Expanded pipeline capacity from the Permian to the Gulf Coast refining region

Reduced sulfur specification for marine bunker fuel in 2020

- The AEO will represent the International Maritime Organizations planned implementation of a 0.5% limit on sulfur content for marine bunker fuel in 2020

- Effects on the volume of U.S. domestic consumption of marine bunker fuel will be relatively small

- Updated international supply/demand curves for petroleum products resulted in a larger low-high sulfur residual fuel oil spread compared to AEO 2017

Revised existing and planned biofuel production capacity and biofuel feedstock supply curves

- Based on EIA's market research, updated existing and planned capacity for various biofuel production facilities

- Using information from a new version of Polysys, updated corn starch, seed oil, and cellulosic biomass feedstock supply curves

- Key assumptions maintained from AEO2017
  - GTL, CTL, BTL (xTL Fischer-Tropsch) expansion are restricted until 2025 at the earliest
  - No changes to California low carbon fuel standards (LCFS) representation

Contacts for Liquid Fuels Markets including biofuels

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Natural Gas Markets

AEO2018 Natural Gas Model Updates

- Implementation of new Natural Gas Market Module (NGMM)
  - Changes between Natural Gas Transmission and Distribution Module (NGTDM) and NGMM
  - Model structure and design
  - Major changes in how natural gas markets are modeled

Transition to new Natural Gas Markets Module (NGMM)

- The NGMM will replace the Natural Gas Transmission and Distribution Module (NGTDM) in NEMS to serve the same following functions:
  - **Represent** the transmission, distribution, and pricing of natural gas in North America, with representations of Canada, Mexico, and LNG trade.
  - **Given** annual regional/sectoral natural gas consumption and short-term regional supply curves, balance supply and demand across the network on marginal cost basis
  - **Determine** annual interregional flows, production, imports, exports, and associated wellhead and delivered natural gas prices
  - **Include** seasonal storage, transmission and distribution pricing, pipeline capacity and expansion, as necessary to capture the impact on the primary outputs
  - **Produce** projections that both align well with history and capture likely future market behavior

- NGMM was designed to solve for flow reversals, is significantly more granular to improve results (particularly marginal pricing), and balances supply/demand (including trade) with a Quadratic program, rather than the heuristic used in the NGTDM

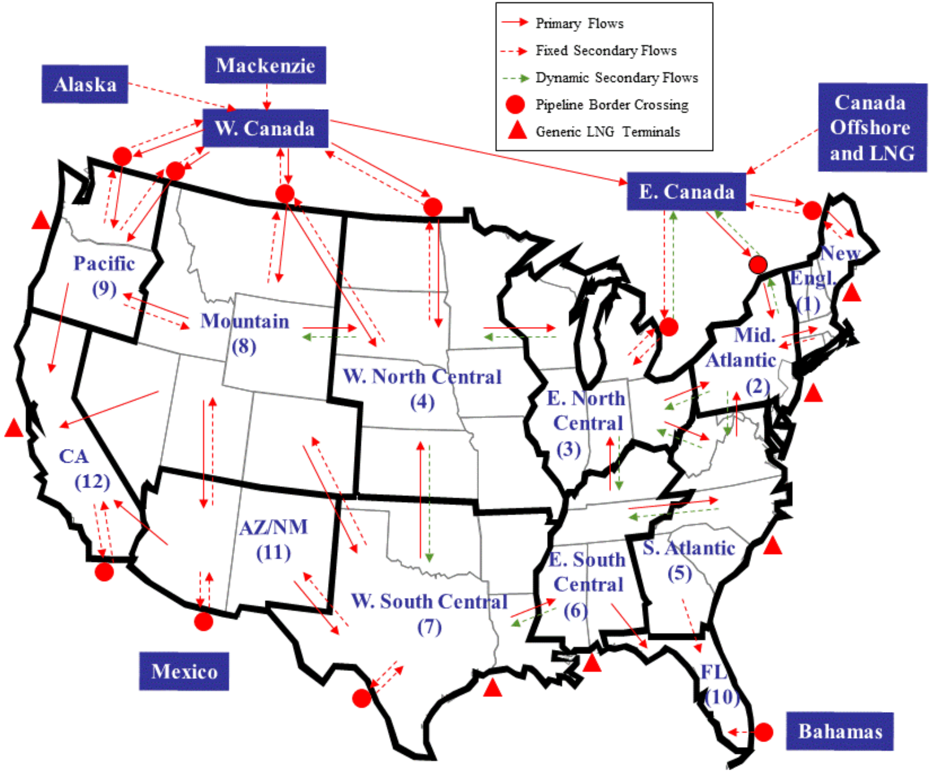
Decision to redesign NGTDM

- Being too constrained to previous year, limits ability to respond to larger annual changes in the market
- Limitations in modeling flows, capacities, and pricing at such an aggregate level – some calibration factors too large
- Heuristic algorithm limited in ability to represent bidirectional flows and changing primary flows
- Model has become difficult to modify and update after many incremental code and data changes, complicating the need for it to be managed by new people

NGMM model requirements

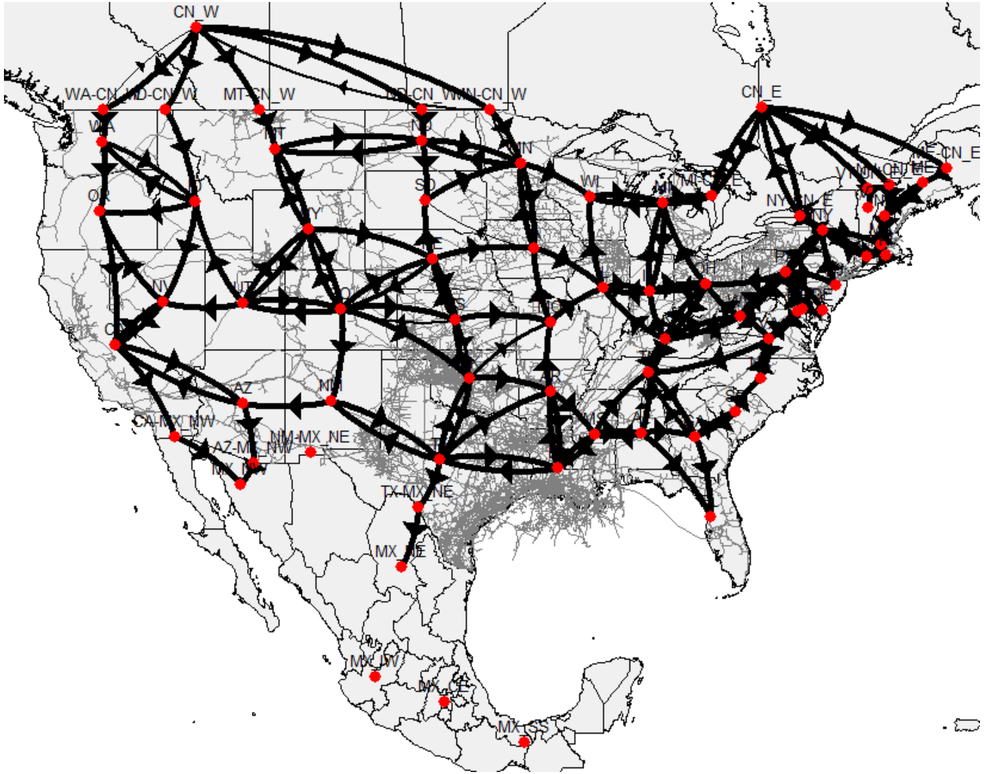
- Project delivered, wellhead, import, and export prices given delivered volumes and regional short-term supply curves
- Balance market and establish production, imports, and exports, as well as lease, plant, and pipeline fuel, and supplemental supplies
- Project region-to-region flows and pipeline capacity
- Produce reasonable projections, align well with history, but capture likely future market behavior (such as under different scenarios)
- Be easier to maintain, update, debug, and learn

NGTDM Network and Structure



- 2 seasons
- 12 U.S. and 2 Canadian demand nodes
- Additional nodes account for international trade
  - Border crossings with Canada (7) and Mexico (3)
  - Generic LNG terminals for each U.S. region with a coastline (8)
- Alaska accounted for outside of network

NGMM Network and Structure



- Transshipment nodes (hubs) at each Lower 48 state, in Canada (2), in Mexico (5), and at each border crossing, including generic LNG points at coastal states
- Solves for monthly/state spot prices at each hub and associated flows between neighboring regions based on variable transport costs and capacity
- Twelve months (solved independently with no interrelationships)
- Capacity expansion and storage withdrawal/injection set separately

Quadratic program (QP) (with linear constraints)

- Max consumer plus producer surplus minus variable transportation costs, subject to mass balance constraints
- Variable transportation costs include pipeline fuel charge and variable tariff
- Output volumes, flows, and marginal prices (fixed charges post-processing)

Decision variables:

Supply
LNG exports
Flow between nodes (supply, hub, demand, LNG exports, storage)
Tariff curve quantity (variable transportation costs)

Primary Constraints:

Mass balance for all node types
Flows between nodes limited to previously projected pipeline capacity

Major model changes

- Implementation of new Natural Gas Market Module (NGMM)
  - Changes between Natural Gas Transmission and Distribution Module (NGTDM) and NGMM
  - Model structure and design
  - Major changes in how natural gas markets are modeled
    - **Variable tariff curves** used to represent pipeline transmission costs
    - **City gate prices** set by econometric estimation
    - **Mexico** now modeled using 5 regions with flows solved endogenously in the QP
    - **LNG export** facility utilization solved endogenously within QP
    - **Canada** supply representation will be done by OGSM

Variable tariff curves

- Based on difference between region/state spot prices
- Components of basis differentials
  - Pipeline fuel charge
  - Variable Tariff
- Assumptions
  - Differences in spot prices are pipeline fuel and variable charges
  - Difference between spot and city gate prices are the fixed charges
- Variable tariff set in a QP using a curve for each arc, function of utilization
- Curves are used as a basis for calibrating the model to history and are held constant throughout forecast, unless assumed otherwise
- Tariff curves based on flow one direction will be assumed to be the same for flow in opposite direction
- Extended beyond existing capacity when projecting capacity expansion, reflecting the consideration of reservation fees

City gate prices: Method

- Use **multiple linear regression** to set state/month city gate prices as a function of state/month spot prices and a factor to reflect fixed charges

$$Citygate_{state,month} = Const_{state} + \alpha_{state} * Spot_{state,month} + \frac{\beta_{state}}{ResComCons_{state,month}}$$

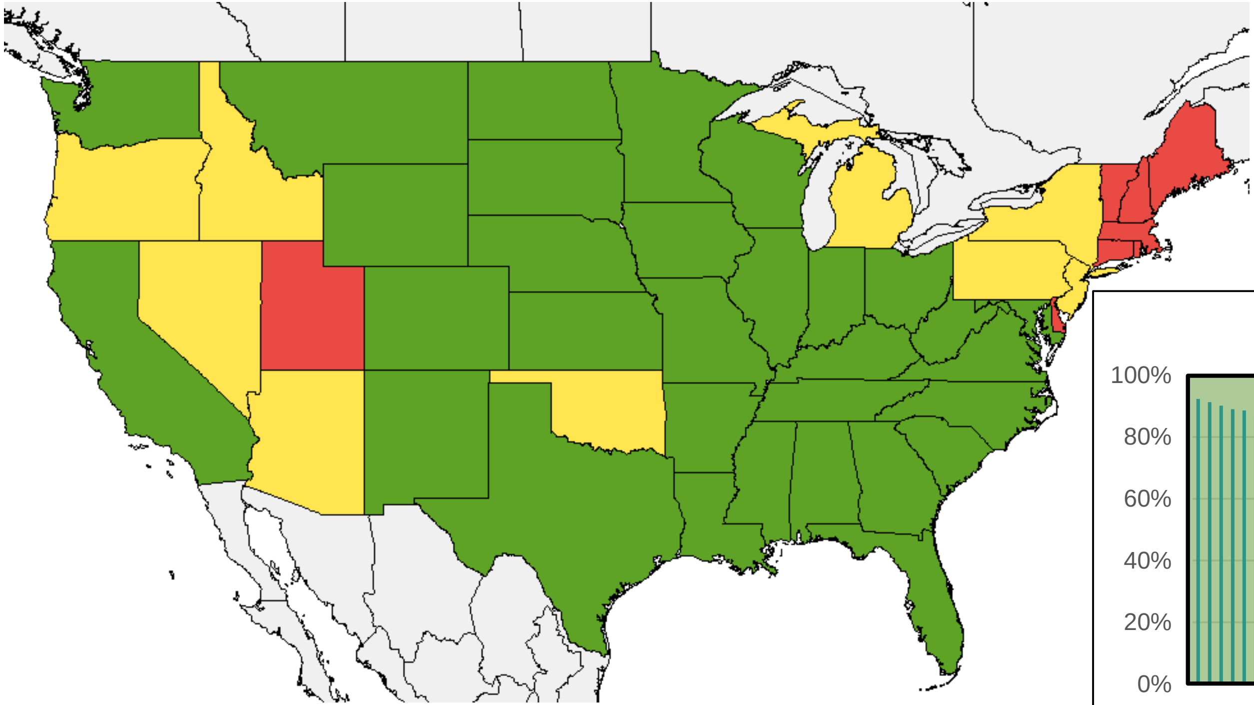
- In **theory**, if LDCs purchase natural gas at close to the spot price, pay an additional fixed charge for transportation and storage, and the residential and commercial consumption is a reasonable proxy for total volumes purchased:
  - $Const_{state}$ would be close to zero,
  - α_{state} would be close to 1
  - β_{state} would equal the annual fixed charge.

- **Pros**: Straightforward and easy to maintain and implement; expect reasonable results, with limited exceptions (e.g., spot price spikes)

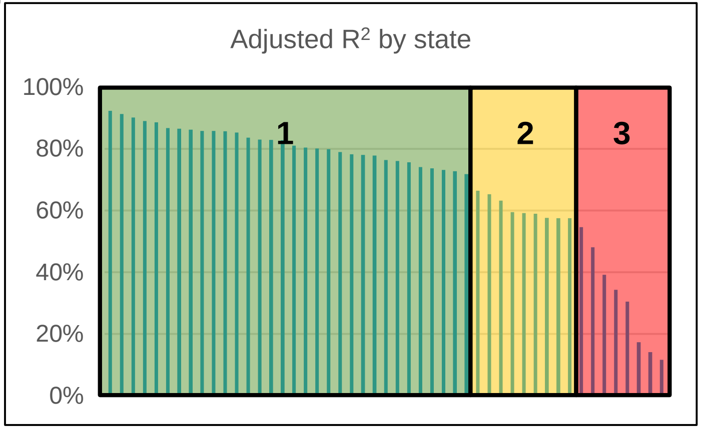
- **Cons**: No direct means to capture factors that might change fixed charges in the future; challenge in addressing exceptions

City gate price multiple regression model:

3 groups of states using different methods

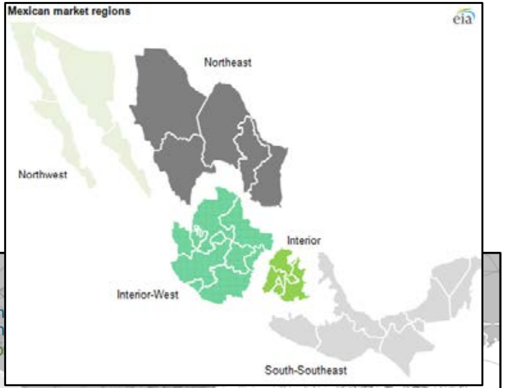


1. All months in same regression
2. Summer and winter (Nov-Mar) regressions
3. Summer regression with winter months set as extrapolation

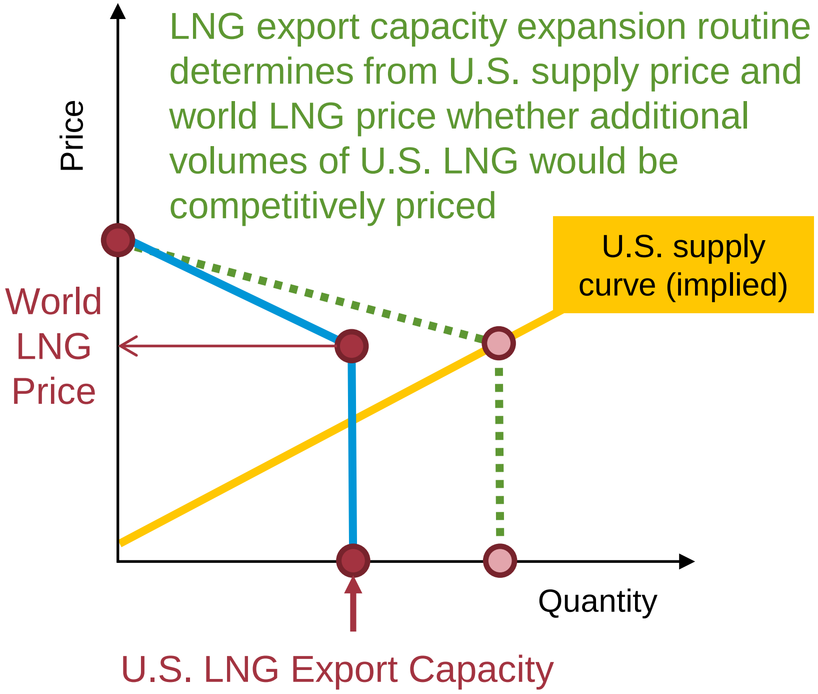


Mexico

- Mexico now modeled by 5 regions (SENER) instead of 3
- Current and future pipeline capacities between regions are modeled
- Considered part of QP; natural gas trade with Mexico is now solved for endogenously



LNG export facility utilization



- U.S. LNG export facility utilization is now determined endogenously (solved for directly in the QP)
- LNG export capacity expansion algorithm based off of that in NGTDM using EIA International Energy Outlook data to project world LNG price
- LNG export facilities under construction are assumed; Elba Island (0.35 Bcf/d in 2018-9) only difference from AEO 2017

Contacts for Natural Gas Markets

For questions about NGTDM, NGMM design, and comparisons between models:

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For questions pertaining to NGMM, design in AIMMS, suggestions for improvements to new model:

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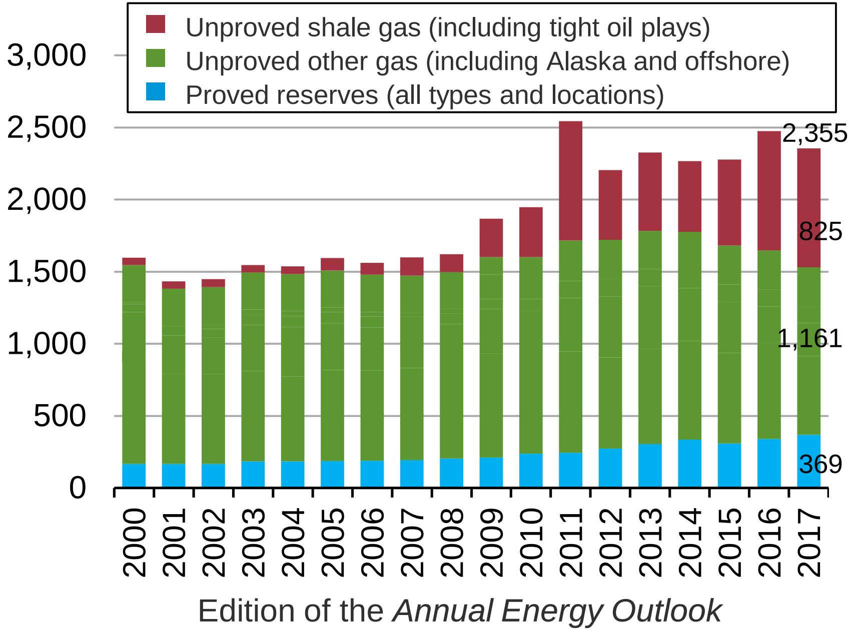
OGSM / Upstream

Discussion topics -- primary AEO2018 OGSM updates

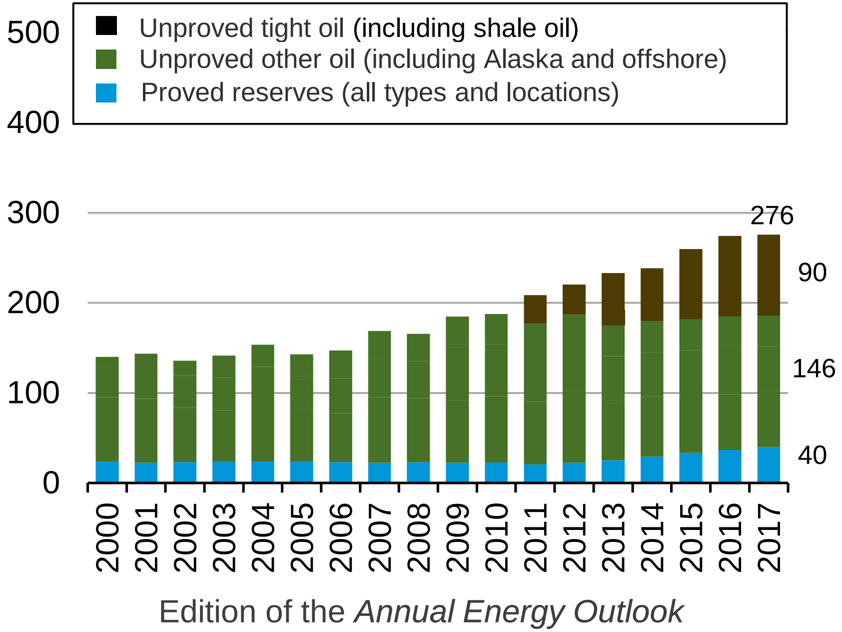
- Estimated ultimate recovery (EUR) of tight/shale oil and gas wells
  - Preliminary unproved technically recoverable resources for select plays
  - Permian Basin EUR distributions: Avalon/Bonespring, Spraberry, and Wolfcamp
  - Appalachian Basin EUR distributions: Marcellus and Utica
- Assumptions for announced discoveries in the GOM
- Additional updates in progress but not included in presentation
  - NGPL and API gravity updates
  - Canada supply representation
  - Technological improvement (learning by doing)

Technically recoverable resources reflect new information; understanding of U.S. shale gas resources has increased substantially in the past decade

U.S. dry gas resources
trillion cubic feet



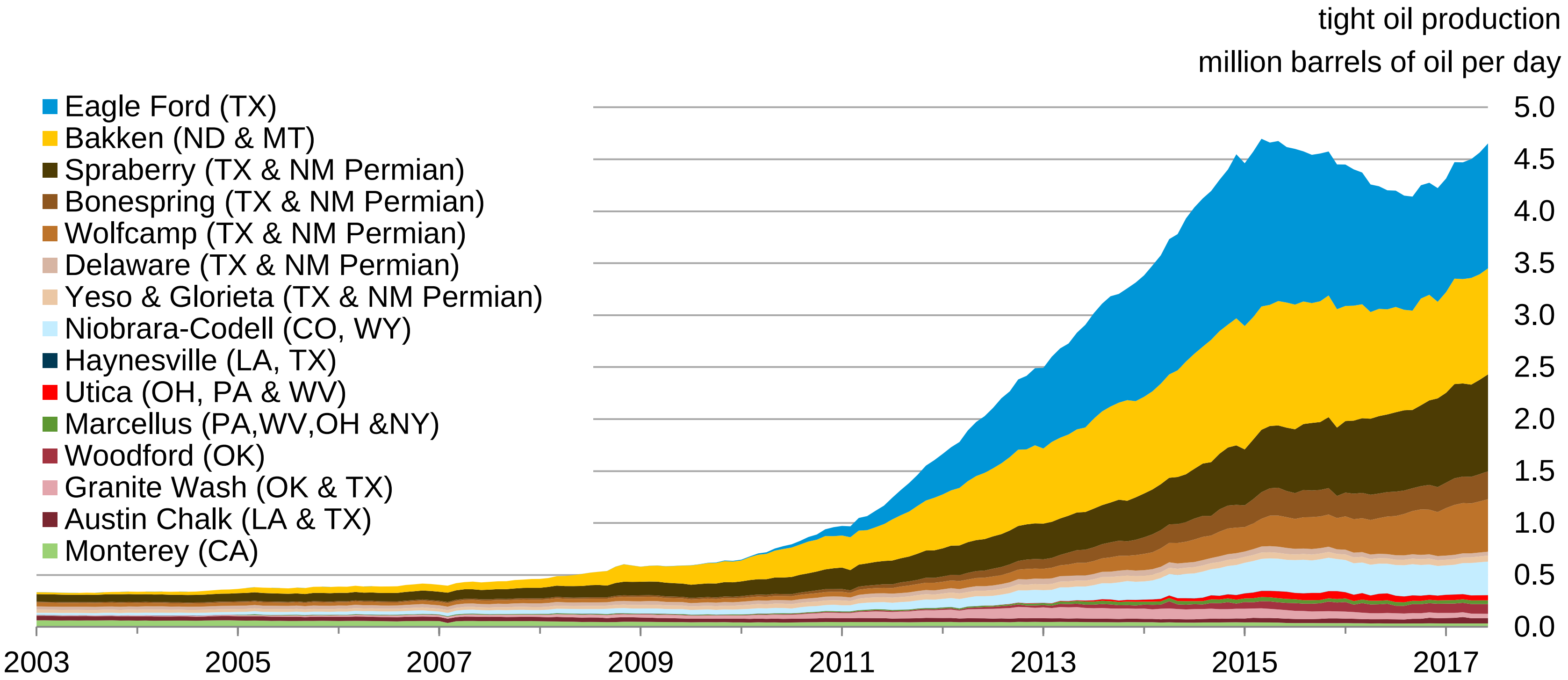
U.S. crude oil and lease condensate resources
billion barrels



Sources: U.S. Energy Information Administration, Annual Energy Outlook 2017 and prior editions.

Note: Resources are as of January 1 of two years prior to the "edition" year of the AEO (e.g. AEO2017 is 1/1/2015). Excludes NGPLs.

U.S. tight oil production – selected plays



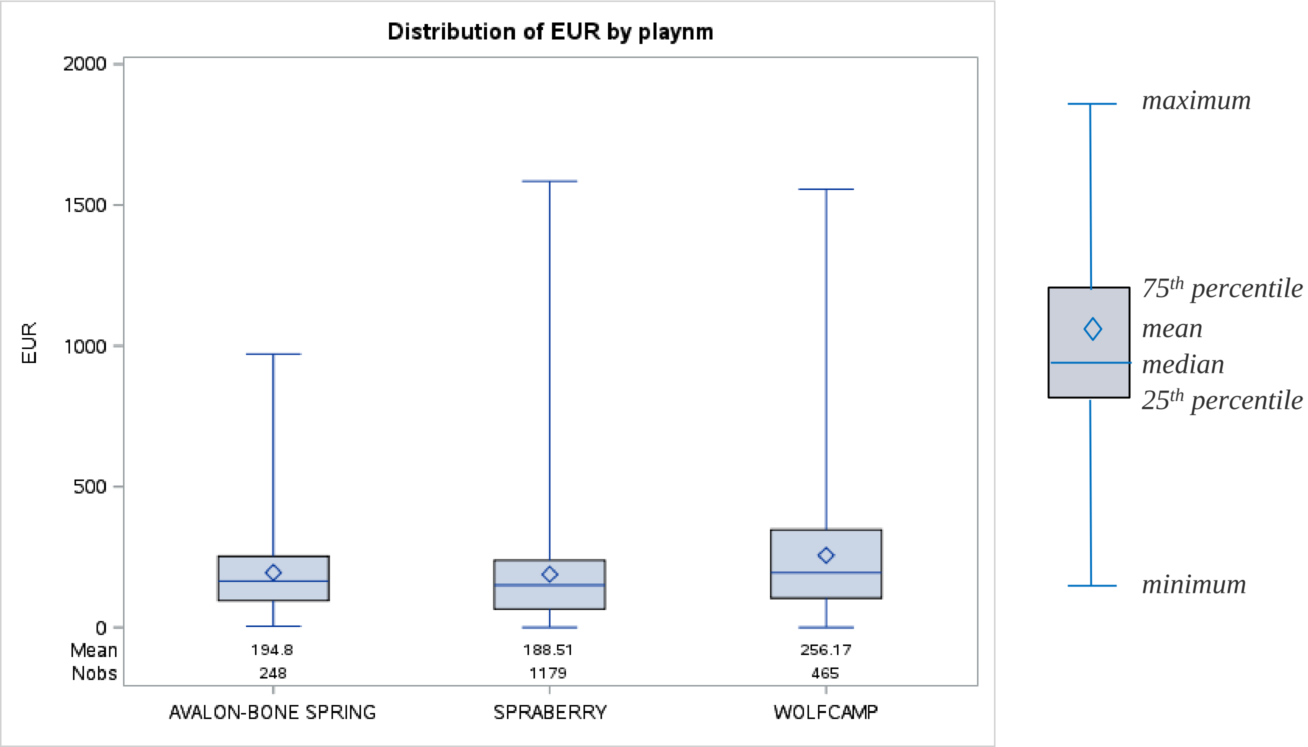
Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through June 2017 and represent EIA's official tight oil estimates, but are not survey data. State abbreviations indicate primary state(s).

Unproved technically recoverable resources in select tight oil plays (as of 1/1/2016)

Tight Oil Play	Crude oil (billion barrels)	Natural gas (trillion cubic feet)	NGPL (billion barrels)
Austin Chalk	5	18	1
Avalon/Bonespring	4	13	1
Bakken	12	8	1
Bakken Three Forks	15	9	1
Buda	4	32	1
Eagle Ford – Oil zone	7	7	2
Spraberry	8	16	2
Tuscaloosa	6	4	0
Wolfcamp	32	102	8
Woodbine	1	0	0
Total	**94**	**209**	**17**

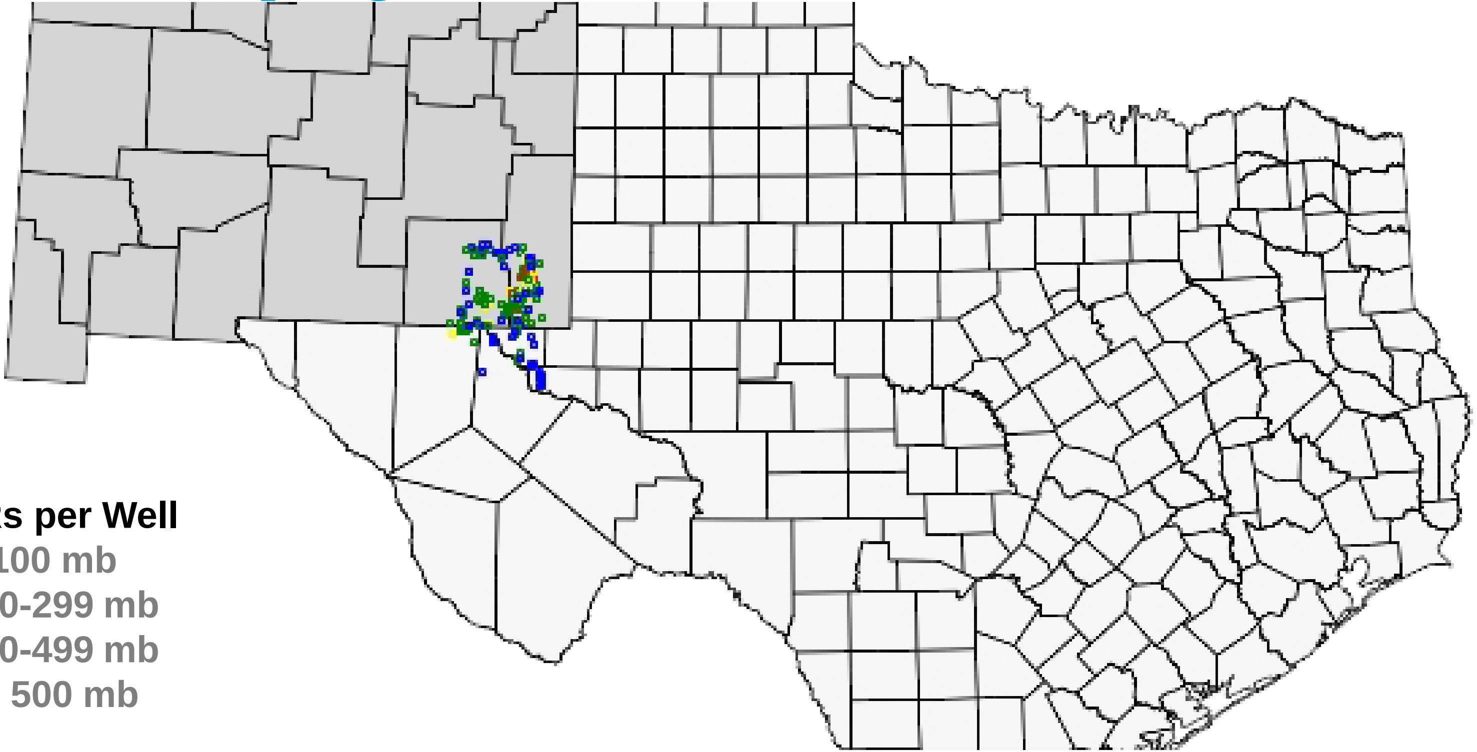
Preliminary estimates assuming 100 acre spacing

Crude oil EUR distribution for 3 key tight oil plays in the Permian Basin, 1,000 barrels per well (mb/well)



Wells drilled in 2016-2017 with at least 4 months of production.

Avalon/Bonespring 2016-2017 wells

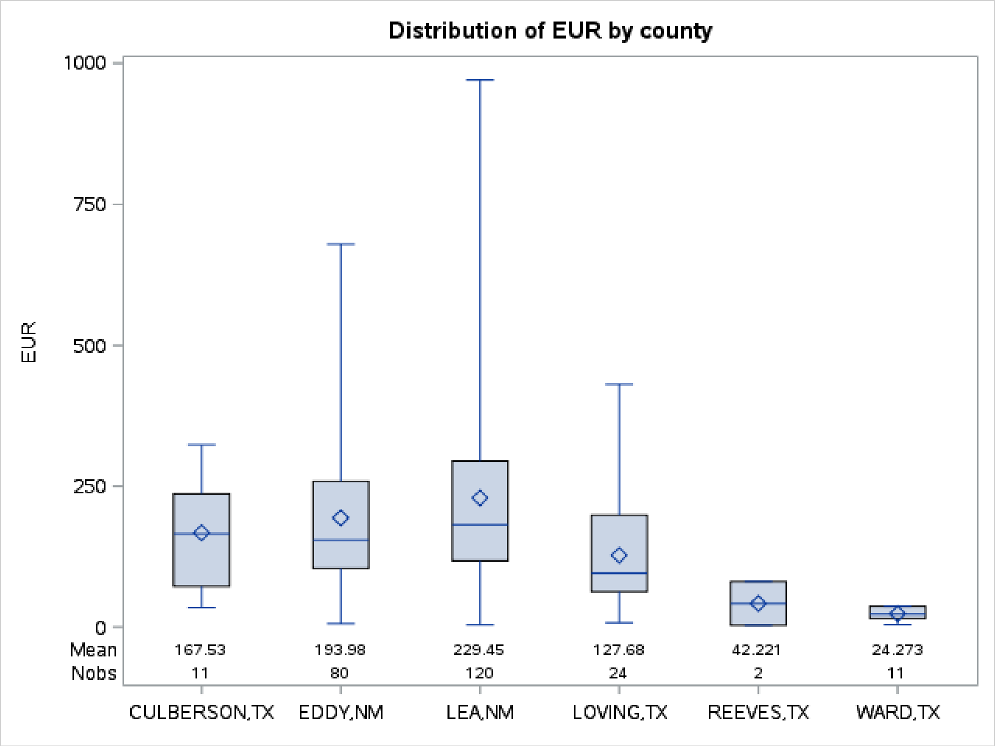


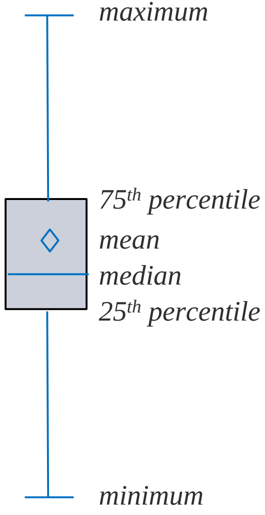
EURs per Well

- < 100 mb
- 100-299 mb
- 300-499 mb
- >= 500 mb

Wells drilled in 2016-2017 with at least 4 months of production.

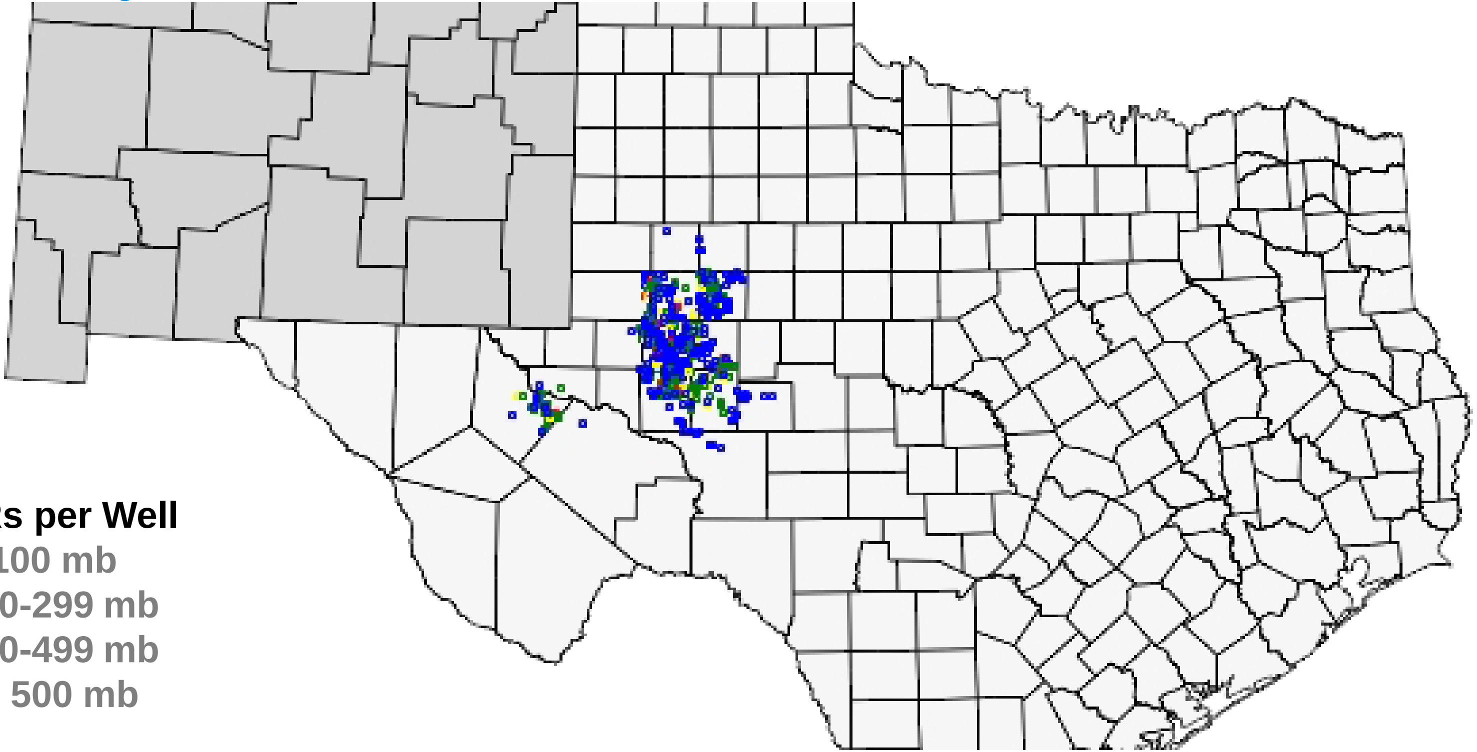
Avalon/Bonespring crude oil EUR distribution, mb/well





Wells drilled in 2016-2017 with at least 4 months of production.

Spraberry 2016-2017 wells



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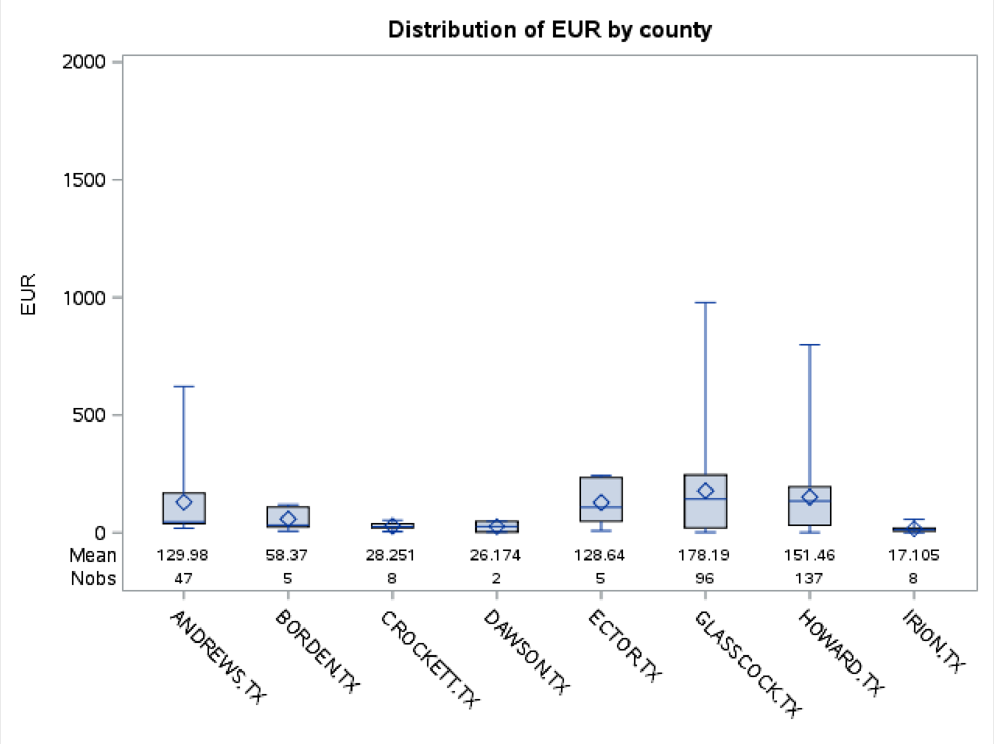

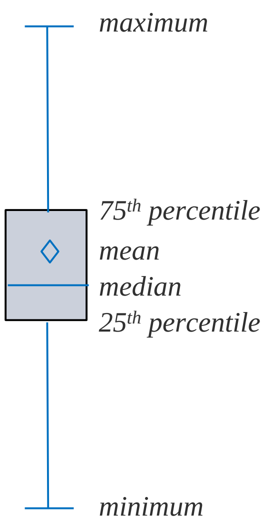

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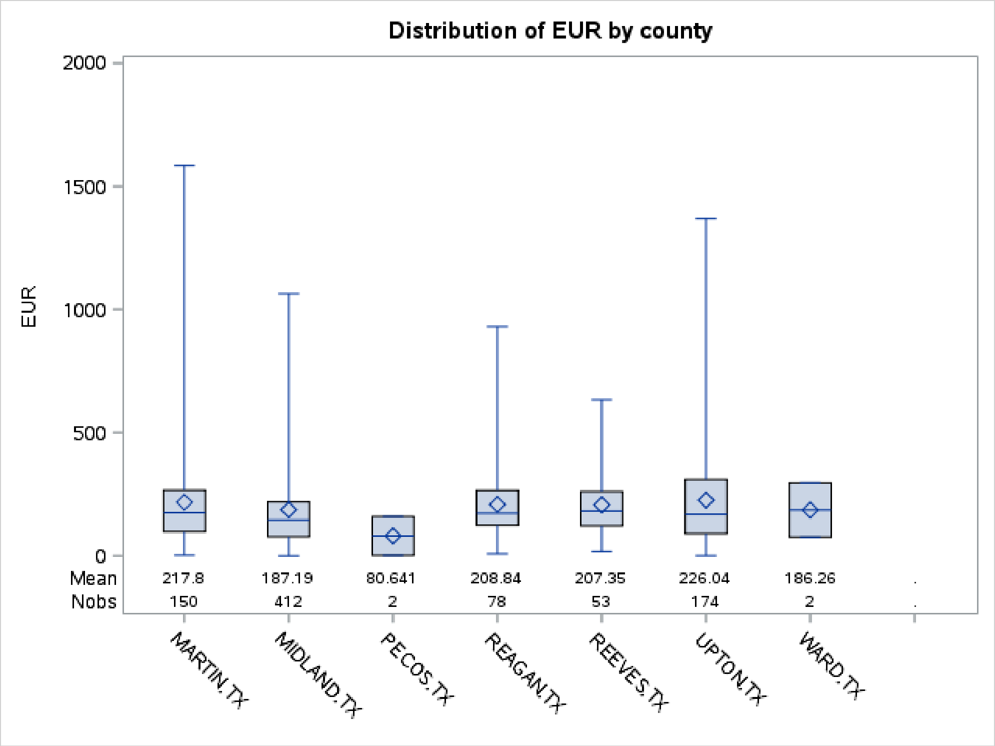
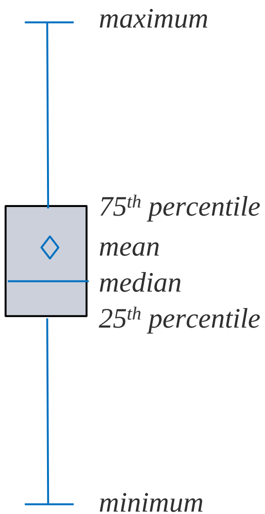
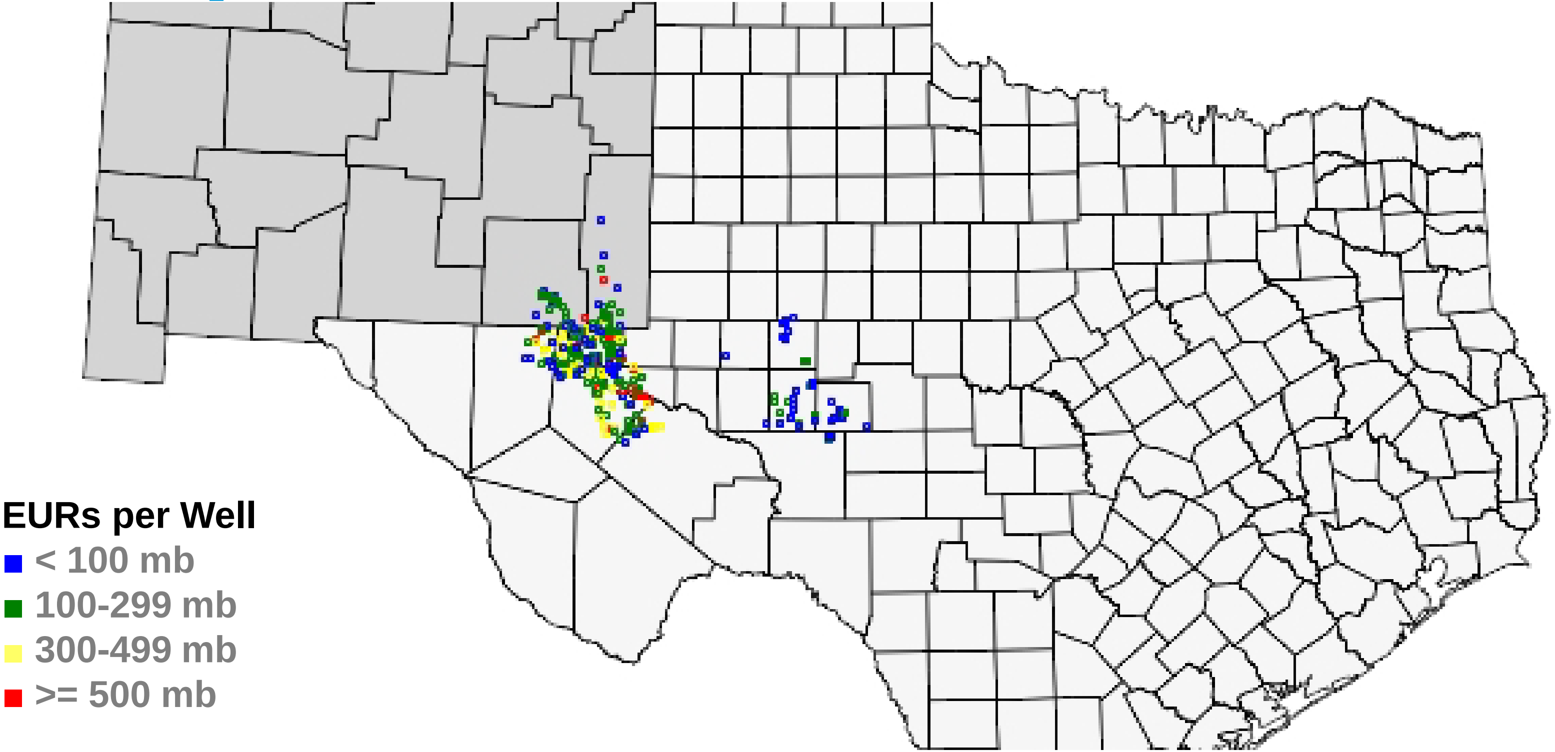
Spraberry crude oil EUR distribution, mb/well





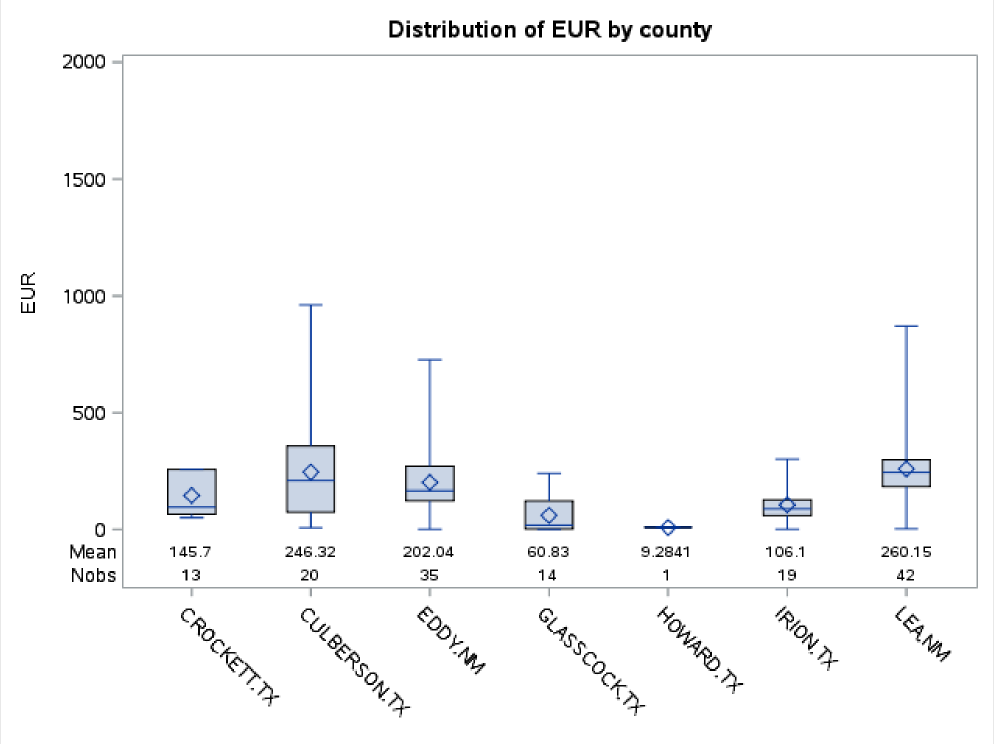
Wells drilled in 2016-2017 with at least 4 months of production.

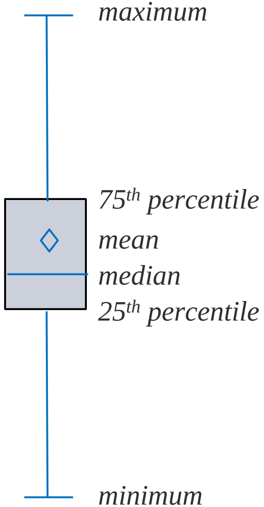
Wolfcamp 2016-2017 wells



Wells drilled in 2016-2017 with at least 4 months of production.

Wolfcamp crude oil EUR distribution, mb/well





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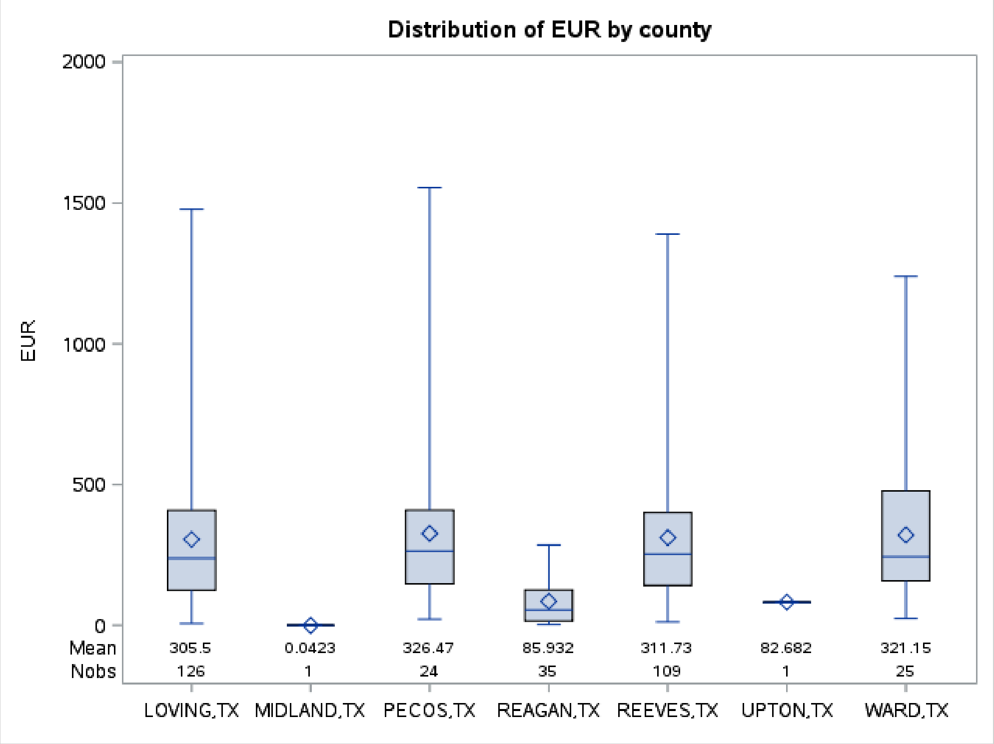
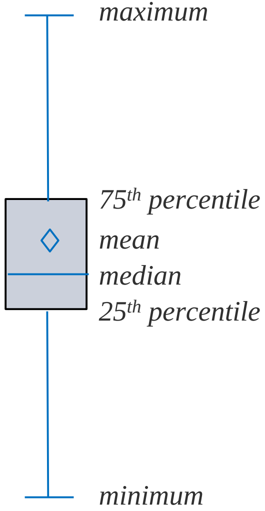
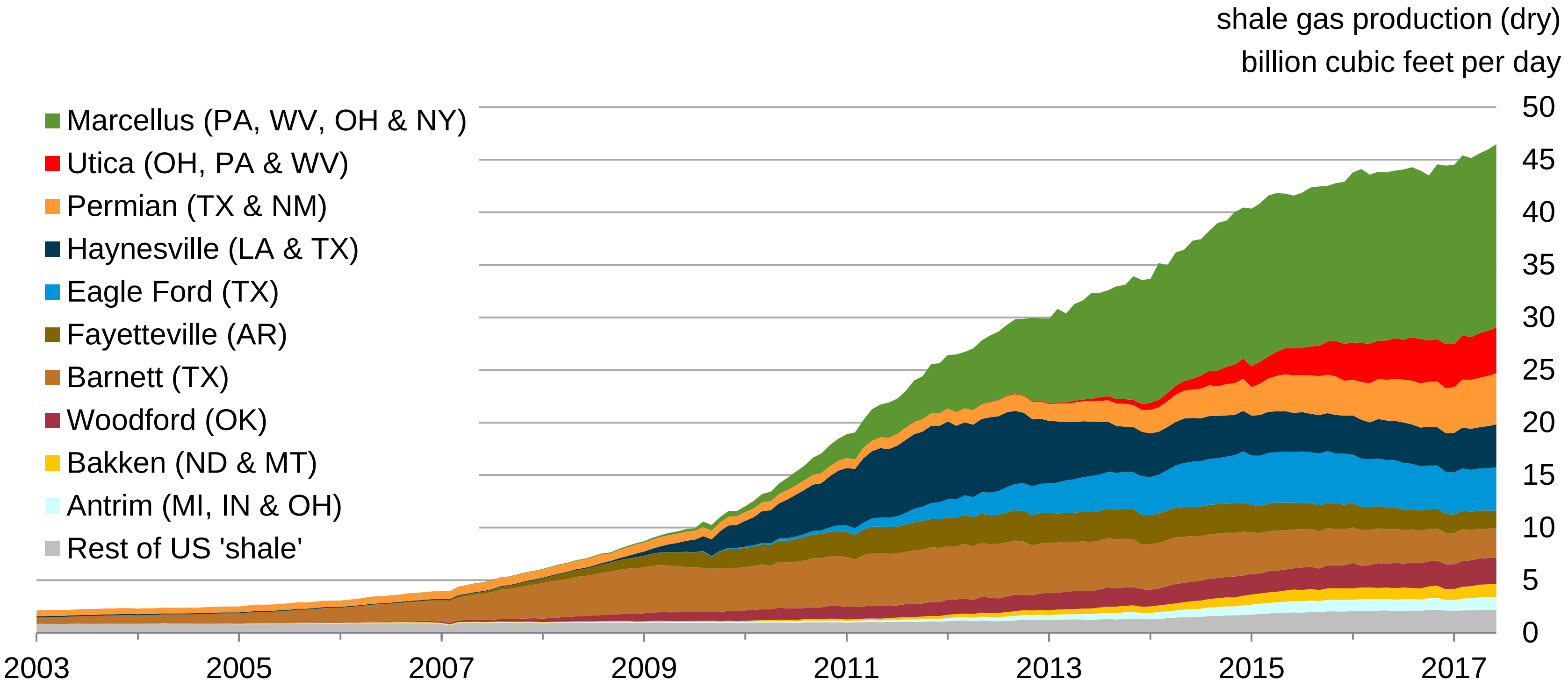




Wells drilled in 2016-2017 with at least 4 months of production.

U.S. dry shale gas production



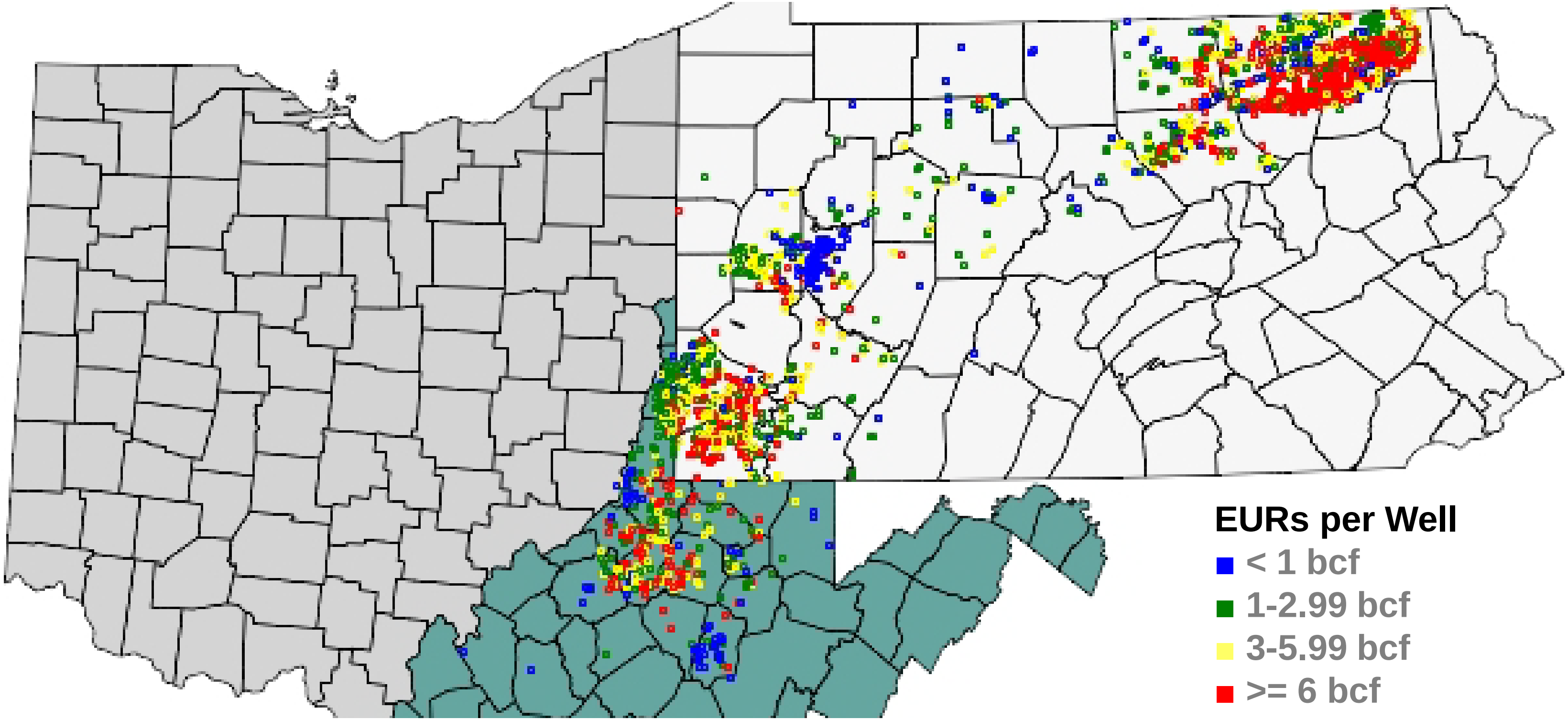
Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through June 2017 and represent EIA's official tight gas estimates, but are not survey data. State abbreviations indicate primary state(s).

Unproved technically recoverable resources in select shale gas plays (as of 1/1/2016)

Shale Gas Play	Crude oil (billion barrels)	Natural gas (trillion cubic feet)	NGPL (billion barrels)
Antrim Shale	-	10.3	0.8
Barnett	0.2	16.9	1.1
Cana Woodford	0.7	12.0	0.5
Devonian Shale	0.7	31.6	1.3
Eagle Ford - Gas zones	6.0	45.5	5.0
Fayetteville	-	39.6	-
Haynesville-Bossier	0.1	88.5	-
Lewis	-	16.3	-
Marcellus	0.6	437.1	20.6
Utica	1.0	217.6	7.3
Total	9.3	915.4	36.6

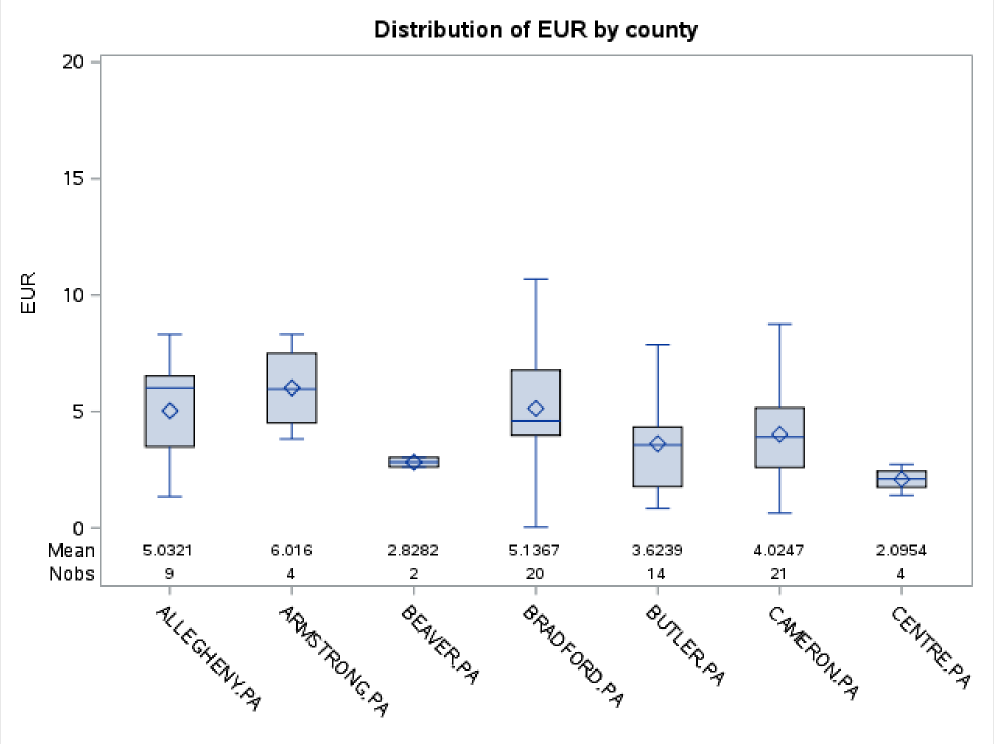
Preliminary estimates assuming 100 acre spacing

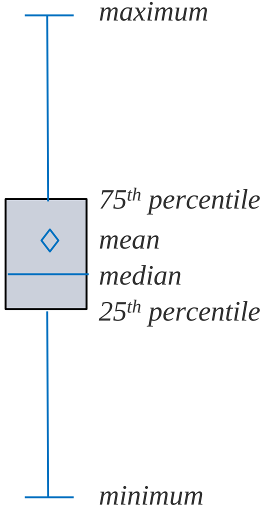
Marcellus 2012-2016 wells



Wells drilled in 2012-2016 with at least 4 months of production.

Marcellus natural gas EUR distribution, bcf/well





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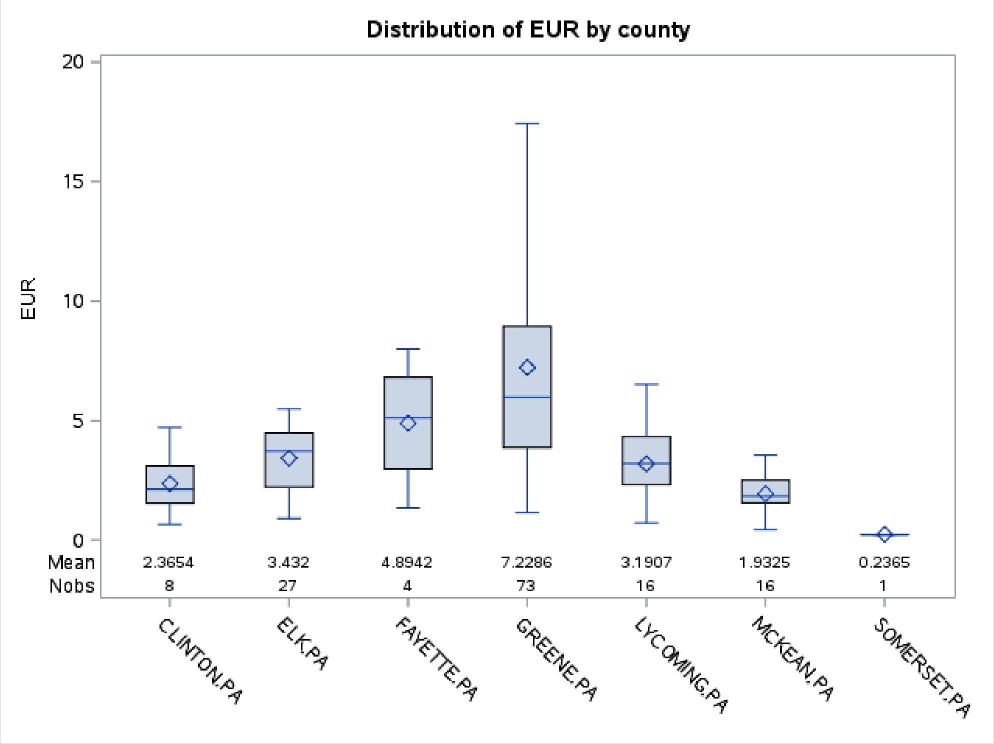
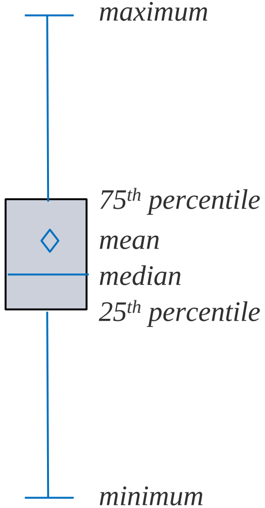
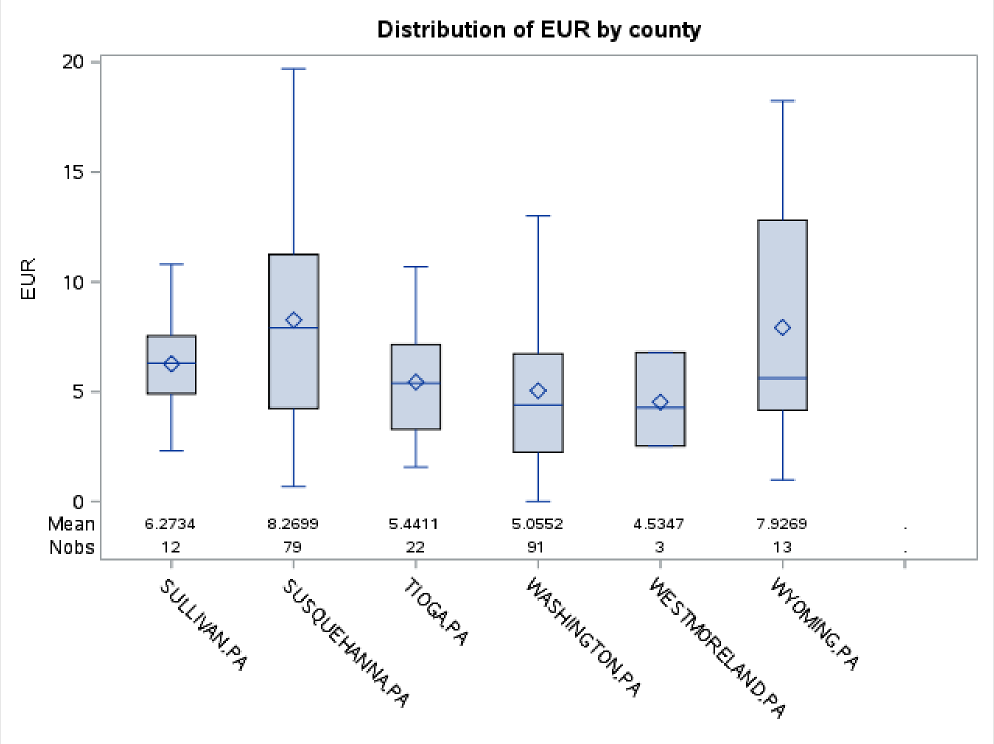
Marcellus natural gas EUR distribution, bcf/well

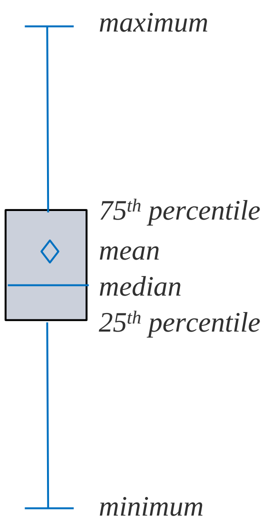




Wells drilled in 2012-2016 with at least 4 months of production.

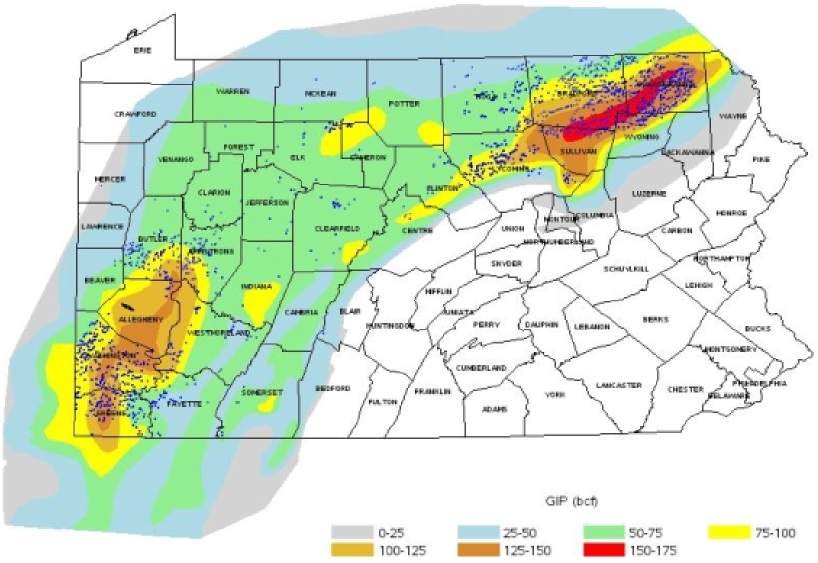
Marcellus natural gas EUR distribution, bcf/well





Wells drilled in 2012-2016 with at least 4 months of production.

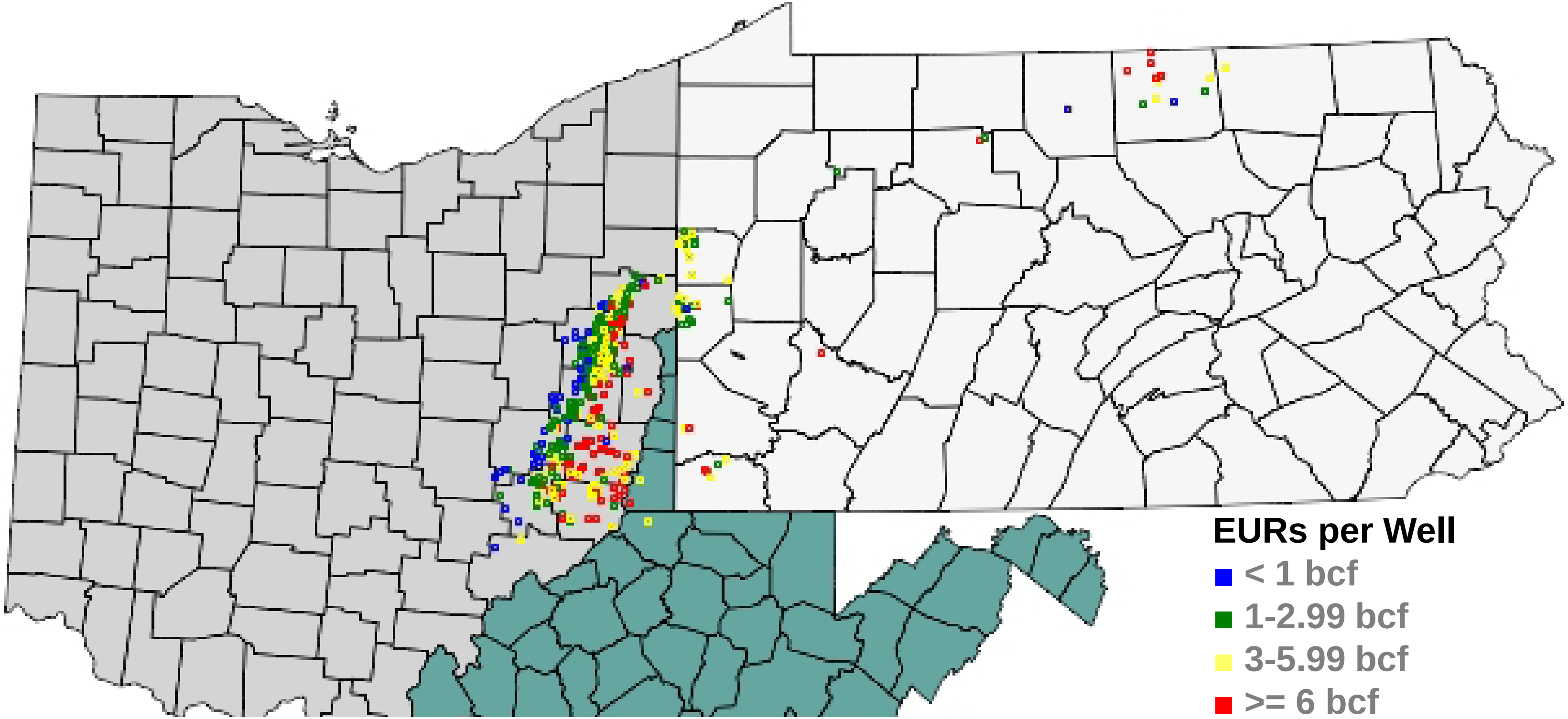
Pennsylvania Marcellus



GIP Category (bcf/sq. mi)	Average EUR (bcf/well)
0-25	1.084
25-50	3.175
50-75	3.814
75-100	5.079
100-125	6.978
125-150	8.501
150-175	10.899

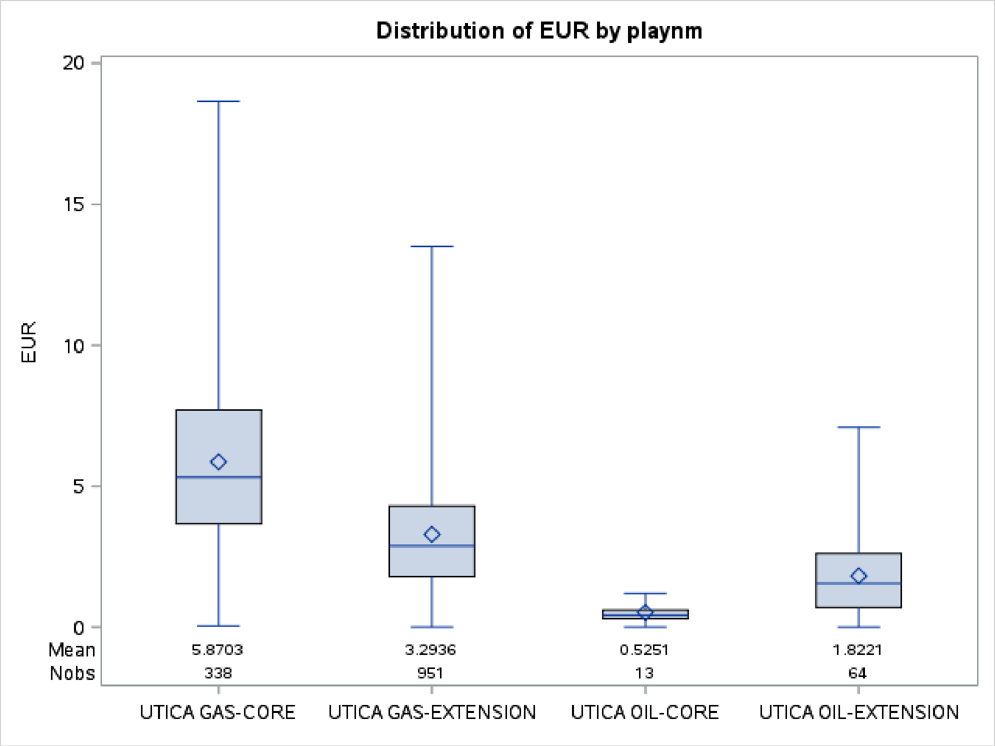
Wells drilled in 2012-2016 with at least 4 months of production. Gas-in-Place (GIP) layers from Range Resources.

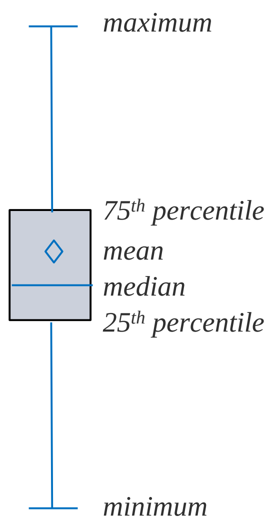
Utica 2012-2016 wells



Wells drilled in 2012-2016 with at least 4 months of production.

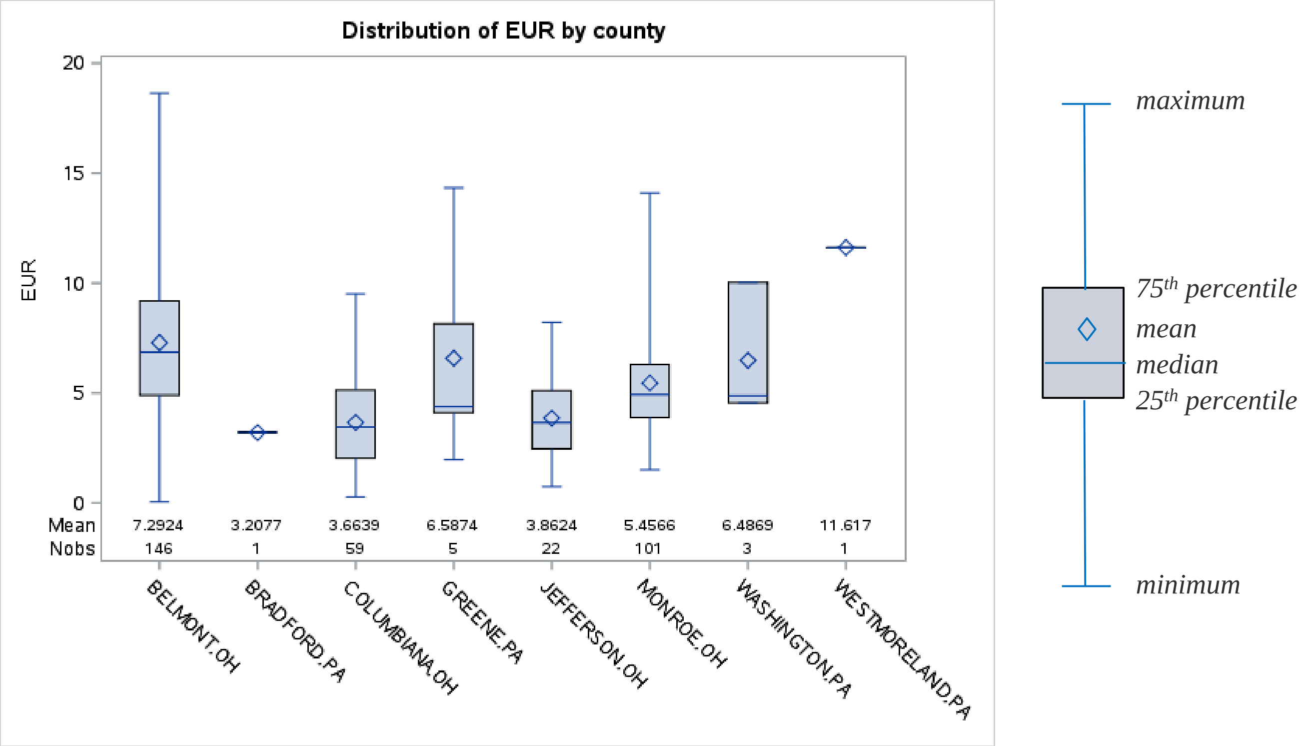
Utica natural gas EUR distribution, bcf/well





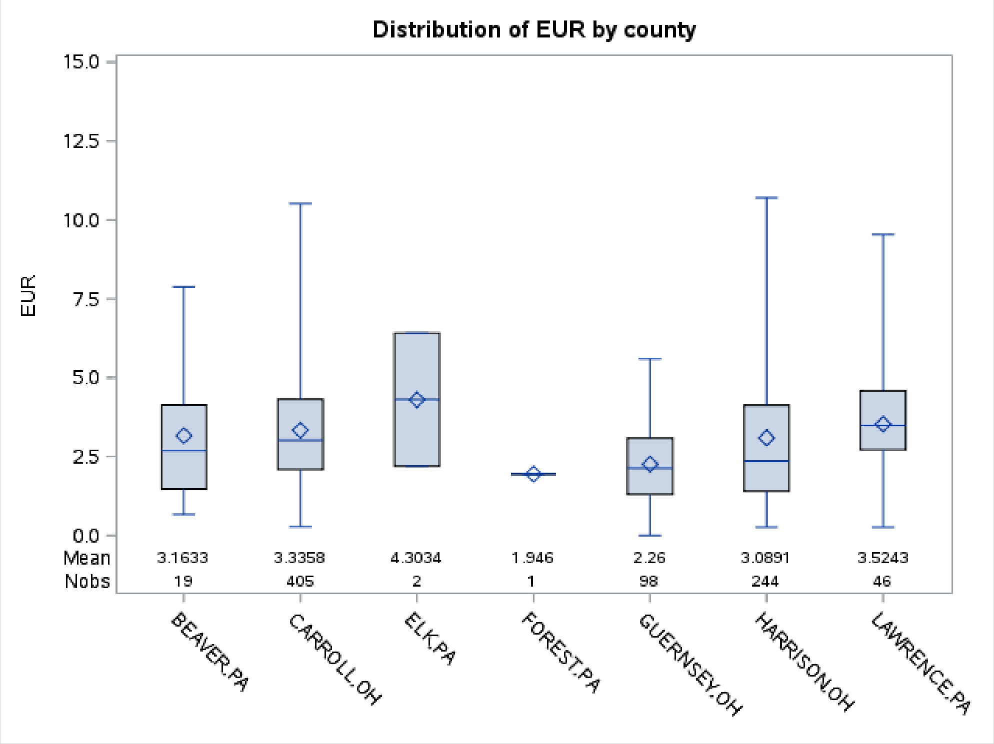
Wells drilled in 2012-2016 with at least 4 months of production.

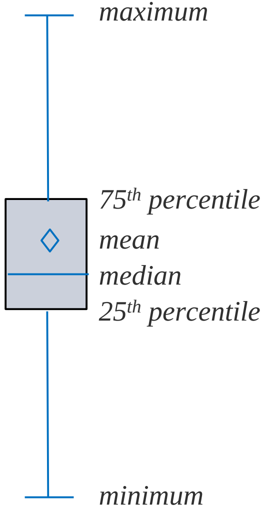
Utica gas-core natural gas EUR distribution, bcf/well



Wells drilled in 2012-2016 with at least 4 months of production.

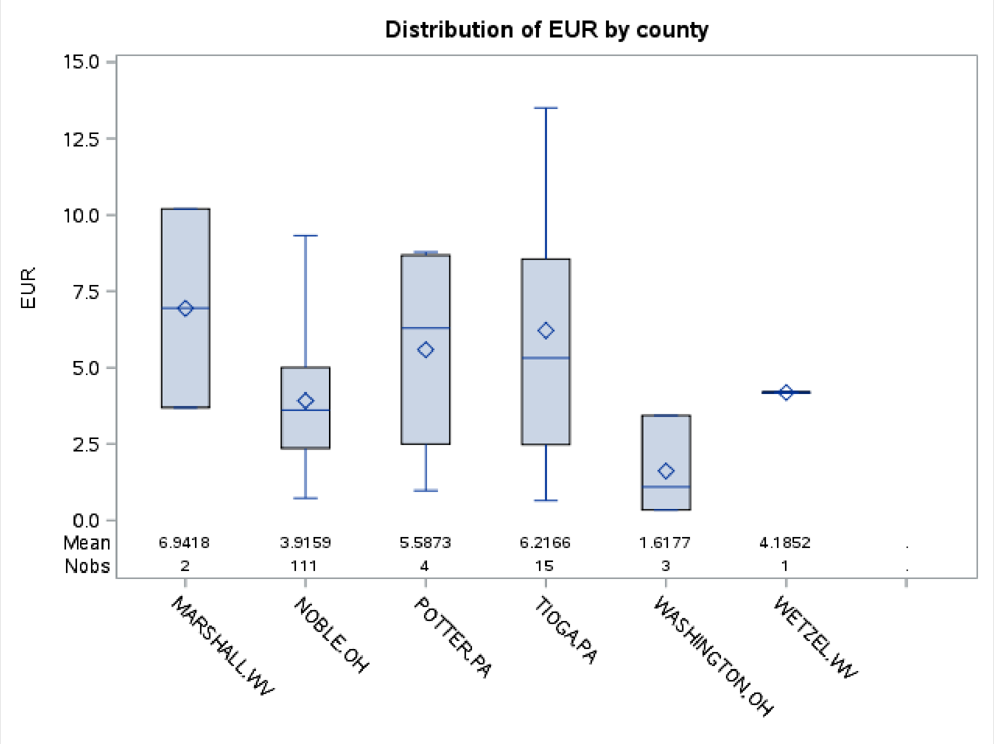
Utica gas-extension natural gas EUR distribution, bcf/well

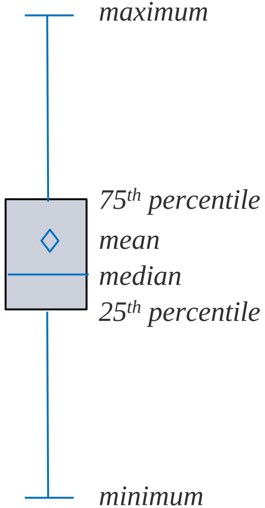




Wells drilled in 2012-2016 with at least 4 months of production.

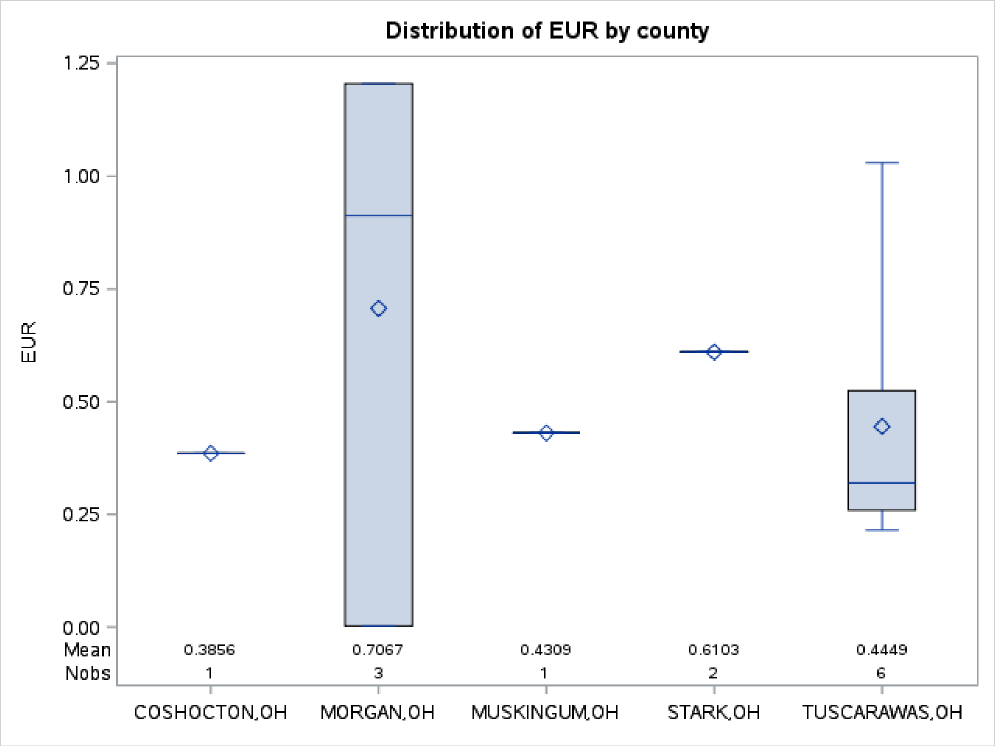
Utica gas-extension natural gas EUR distribution, bcf/well

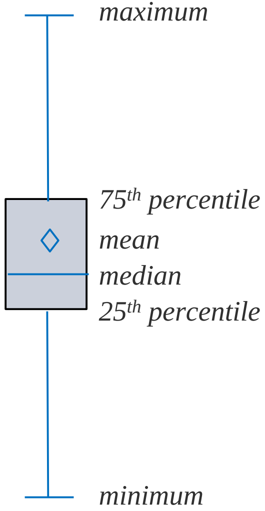




Wells drilled in 2012-2016 with at least 4 months of production.

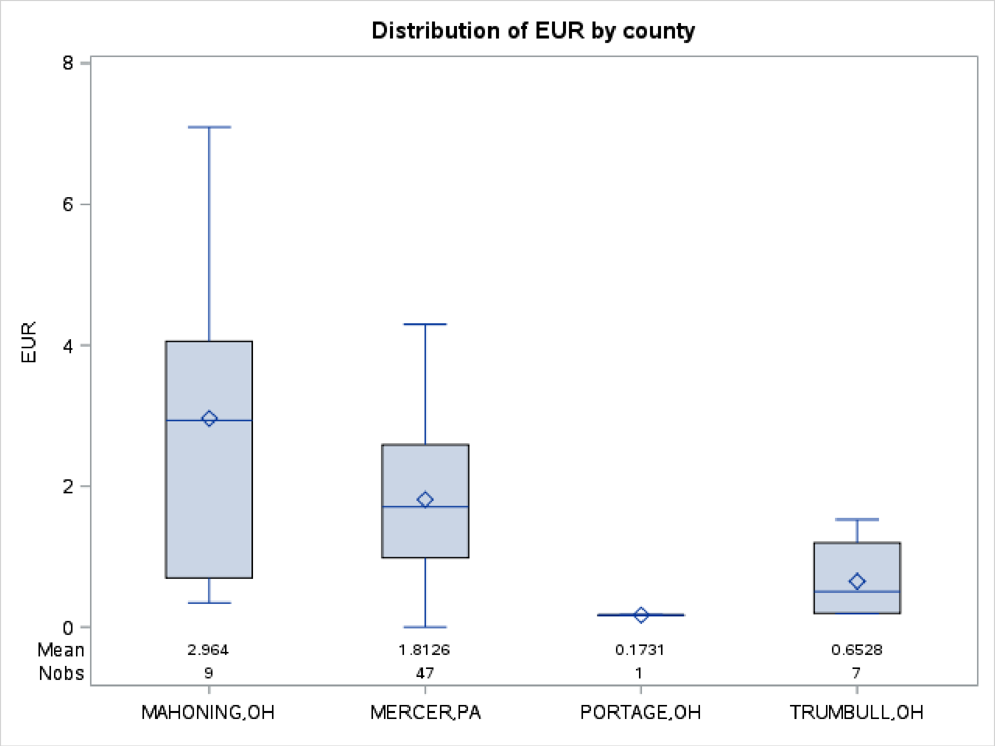
Utica oil-core natural gas EUR distribution, bcf/well

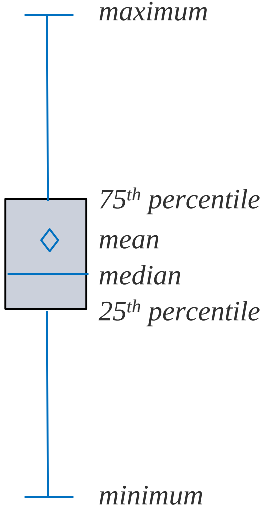




Wells drilled in 2012-2016 with at least 4 months of production.

Utica oil-extension natural gas EUR distribution, bcf/well





Wells drilled in 2012-2016 with at least 4 months of production.

Major deepwater announced discoveries

Field nickname	Production Start Date	Oil Peak Production Volume (Mb/d)	Gas Peak Production Volume (MMcf/d)
Horn Mountain Deep	2017	25	0
Son of Bluto 2	2017	20	0
Amethyst	2018	10	15
Stampede-Knotty Head	2018	40	0
Stampede-Pony	2018	40	0
Otis	2018	10	75
Rydberg	2019	10	0
Tiber	2019	50	0
Tomcat	2019	10	20
Kaikias	2019	30	0
Bushwood	2019	15	0
Gotcha	2019	10	0
Diamond	2020	0.5	50
Fort Sumter	2020	0	0
Hadrian North	2020	100	75
Kaskida	2020	50	100
Vicksburg	2020	87.5	20
Vito	2020	25	0
Yucatan North	2020	10	0

Field nickname	Production Start Date	Oil Peak Production Volume (Mb/d)	Gas Peak Production Volume (MMcf/d)
Caicos	2020	0	0
Cheyenne East	2020	0.5	30
Shenandoah	2020	30	0
Appomattox	2020	87.5	60
Phobos	2020	10	0
Gila	2020	50	0
Holstein Deep	2020	20	50
Tahiti 2 [vertical expansion]	2020	20	0
North Platte	2021	45	100
Mad Dog Phase 2	2021	140	200
Parmer	2022	10	30
Guadalupe	2024	35	0
Katmai	2024	10	0
Gettysburg	2024	25	50
Leon	2024	25	0
Anchor	2025	60	0
Yeti	2025	25	0
Sicily	2025	0	0

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We welcome feedback on our assumptions and documentation

- Working group meetings http://www.eia.gov/forecasts/aeo/workinggroup/

- The AEO Assumptions report http://www.eia.gov/forecasts/aeo/assumptions/

- NEMS Model Documentation
  - Oil and gas supply https://www.eia.gov/outlooks/aeo/nems/documentation/ogsm/pdf/m063(2017).pdf
  - Natural gas transmission and distribution http://www.eia.gov/forecasts/aeo/nems/documentation/ngtdm/pdf/m062(2014).pdf
  - LFMM https://www.eia.gov/outlooks/aeo/nems/documentation/lfmm/pdf/m059(2014).pdf

- Working papers series http://www.eia.gov/workingpapers/

Thank you

Next Working Group Meeting

Tentatively planned for September 2017.

Will present preliminary results for *AEO2018*.