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EIA-914 Monthly Crude Oil, Lease Condensate, and Natural Gas Production Report Methodology

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EIA-914 Monthly Crude Oil, Lease Condensate, and Natural Gas Production Report Methodology

Executive summary

The U.S. Energy Information Administration (EIA) currently collects survey data directly from crude oil and natural gas producers in 15 states,¹ the federal Gulf of Mexico (GOM), and other states,² and uses the survey data to estimate total production for the 15 states, the GOM, other states, and the United States. This methodology applies to estimates for natural gas production beginning with January 2015. This methodology also applies to crude oil (and lease condensate) produced in Arkansas, California, Colorado, Kansas, Louisiana, Montana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming, and the federal Gulf of Mexico.

EIA continues to rely on data from state and other federal agencies to estimate crude oil production for the states within other states, which are not separately surveyed, using the Average Lagged Ratio (ALR) method.³ The ALR method only applies to crude oil (including lease condensate) for all states through December 2014, and only to crude oil (including lease condensate) for the states included in other states thereafter.

EIA estimates monthly production for all individually sampled states by modeling the relationship between final state-level data from DrillingInfo (DI), a third-party vendor of well-level data collected by state agencies, and data reported on the EIA-914 survey. This relationship is modeled using a Weighted Least Squares (WLS) linear regression.

Summarizing the estimation process in terms of approximate percent of U.S. oil production:⁴

- 92% based on WLS estimates
- 5% is state-reported data from Alaska
- 3% based on ALR estimates⁵

¹ The states directly sampled by Form EIA-914 are Arkansas, California, Colorado, Kansas, Louisiana, Montana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming, and the federal Gulf of Mexico.

² The states not directly sampled and included in Other States are Alabama, Arizona, Florida, Illinois, Indiana, Kentucky, Maryland, Michigan, Mississippi, Missouri, Nebraska, Nevada, New York, Oregon, South Dakota, Tennessee, and Virginia, and federal Pacific Offshore.

³ The Average Lagged Ratio methodology used for EIA crude oil production estimation is available at <http://www.eia.gov/petroleum/supply/monthly/pdf/crudemeth.pdf>.

⁴ The percentages of U.S. natural gas production for each, based on 2013 volumes, differs slightly as none are estimated using the ALR method. The breakout is: 89% based on WLS estimates and 11% is state reported by Alaska. Note that 3% of the volume estimated using WLS is for Other States, which are not individually estimated with the ALR method, which is used only for oil production.

⁵ EIA continues to estimate all state crude oil production using ALR as a quality check of the WLS estimates. If EIA-914 sample data for a state do not pass quality control checks, then the ALR estimate for the state temporarily may be substituted for the WLS estimate for the state.

Background

The EIA-914 began collecting natural gas production data in 2005 from Texas, Oklahoma, Louisiana, New Mexico, Wyoming, the federal Gulf of Mexico, and other states (as a group) excluding Alaska. In 2010, EIA updated and improved the sampling and estimation methodologies. In 2015, EIA improved the EIA-914 form to begin collecting crude oil and lease condensate production⁶, oil and lease condensate sales volumes by API gravity categories,⁷ and expanded the collection to 16 individual states/areas adding Arkansas, California, Colorado, Kansas, Montana, North Dakota, Ohio, Pennsylvania, Utah, and West Virginia, while the other states category was reduced in coverage from 28 states/areas to 18 states/areas.

There are two parts to the EIA-914 process: the sampling and the estimation. There are significant similarities to the sampling and estimation [methodologies](#) used through May 2015 reporting,⁸ and each is described separately below.

Sampling methodology

The EIA-914 report collects crude oil and lease condensate (combined), and natural gas production volume data on a monthly basis by state from a sample of well operators (oil and gas companies). (Hereafter crude oil and lease condensate are referred to as oil, and natural gas as gas.) In addition to oil production volumes, oil sales volumes for nine API gravity categories are also collected by state/area.

Two samples, one for oil and one for gas, are drawn each month for each state/area (including other states). Each is a cutoff sample with the cutoff production rate designed to provide 85 percent production coverage for both oil and gas in every state/area. A sampled company reports all of its operated oil and gas production for every state where it operates oil and gas wells if it is sampled in any state for either its oil or gas production. This means that many states will have more than 85 percent coverage and will yield a lower 48 states coverage of roughly 90 percent for both oil and gas production.

The total sample consists of approximately 450 operators out of roughly 13,000 oil and gas operators in the United States. The sampled group of companies can change by as much as a dozen, but usually by only four or five, each month by adding and dropping companies, and accounting for company acquisitions and sales. If a sampled company's oil and gas production falls below the cutoff production rates in every state for six consecutive months, then it is dropped from the sample. If a nonsampled company's oil or gas production exceeds a sample cutoff rate in any state for four consecutive months, it is added to the sample. Monthly sampling in this manner keeps the sample current and avoids a major change in the sample caused by less frequent updating while minimizing sample turnover.

⁶ Although the survey specifies that respondent companies report their production volumes, some companies are only able to report their crude oil and lease condensate sales volumes. EIA expects that the deviation between a company's production and sales will not be a large amount and that sales typically are a reasonable proxy for production.

⁷ During the public comment period for the expanded form, some companies reported they can more easily collect and report API gravity information by production rather than sales. As a result, some respondent companies are reporting API gravity for their production volumes rather than their sales volumes.

⁸ Natural gas estimates for April using this new methodology were released at the end of June 2015. At that time revised estimates for January-March using this new methodology were also released.

Data preparation

A file containing each company's latest oil and gas production by state is prepared every month for use in the monthly sample selection process. The latest available DrillingInfo (DI) monthly production data are used to create this file (DI is a commercial vendor of state oil and gas production data). DI acquires well or lease level data from state regulatory agencies, then places these data in a database format, which it sells to third parties, such as EIA. An updated DI database is acquired by EIA every month. The DI database is used for both the sampling and the estimation processes. Data for four of the smaller producing states are not available from DI. For Illinois, Indiana, Kentucky, and Tennessee, annual production data from the EIA-23 survey (Annual Survey of Domestic Oil and Gas Reserves) are used to supplement the state data from DI. Hereafter, references to state data from DI in this document include supplemental data from the EIA-23 report for these four states.

Cutoff sample

The oil and gas production cutoff rates for each state/area are determined once per year and then used every month until the next year. The cutoff rates are designed to yield sample coverage of at least 85 percent of the total oil and gas production of each state. Although operators are selected based on their oil or gas production in a particular state/area, all operators added because of their oil production have an additional selection criterion of producing at least 500 barrels per day in at least one state/area.⁹ This constraint limits the number of very small operators in the sample. The application of the 500 barrel per day minimum roughly reduces the sample size by one-half, but also yields less than the 85 percent target coverage for oil in a few states. The loss of some state coverage is an acceptable compromise to dramatically reduce the reporting burden on the industry. Testing has shown that this sample methodology yields reasonable relative standard errors.¹⁰ The sample is based on coverage of production volume to guard against model failure (see the section "Potential Sources of Errors").

Adding and dropping companies

Each operator's recent monthly oil and gas production data are compared to the sampling cutoff rates for oil and gas in each state (according to the sampling criteria stated above) to determine if a company is in the sample each month. Companies meeting the criteria to be dropped from the sample are contacted to confirm that their continued production will remain below all cutoff rates in all states for the foreseeable future. Companies providing confirmation are dropped from the sample. Likewise, companies meeting the criteria to be added to the sample are notified of their selection and given instructions on how to proceed with monthly reporting. Companies with production in DI above the cutoff for four consecutive months in any state for oil or gas are added to the sample. Conversely, companies with survey-reported production below the cutoff for six consecutive months for oil and gas in all states where they operate are dropped from the sample.

⁹ Many included operators do produce less than 500 barrels per day of oil in at least one state/area, but, if they are selected because of their oil production, they produce at least 500 barrels per day in the state/area for which they are included in the sample. Operators selected because of their natural gas production may produce less than 500 barrels per day of oil in all the states/areas in which they operate, but this does not eliminate them from the sample.

¹⁰ See "Sampling Error" in the "Potential Sources of Errors" section below for more discussion of relative standard errors.

Other ways companies are added or dropped

Mergers and acquisitions, or buying and selling properties can cause a company's production level to move above or below a sample cutoff value. EIA accommodates the larger company changes in the sample as soon as possible after they occur. Large events in terms of overall production, or share of production in one or more states/area, that involve a company currently in the sample and another that is not in the sample are the most important to quickly accommodate in order to minimize estimation errors (see the section "Potential Sources of Errors"). These larger events are usually in news reports, newsletters, press releases, industry trade journals, and other media outlets. Both companies involved in the transaction may be contacted to assure continued full accounting of production without potential double counting. Accommodating minor events involving small companies or small volumes of production usually are delayed if they involve only companies in the nonsampled group. Most smaller mergers and property sales outside the sample are unknown. Information on mergers and property acquisitions is also requested on the EIA-914 form.

Other states group

The other states group of states accounts for roughly 3 percent of lower 48 States oil and gas production and includes 18 states. Some of these states are extremely small producers. Other states also includes four states (Illinois, Indiana, Kentucky, and Tennessee) that are not in the DI database. Some of the 18 states do not require any production reporting for regulatory purposes, or only require annual reporting. The largest producing states within other states typically dominate the sample and the smallest producing states may be underrepresented by sample companies chosen because of their production in other states. Also, sampling is affected by the absence of a precise and complete list of all producers and their production in other states. These circumstances make it difficult to quantify sample coverage for other states.

Estimation methodology

Weighted Least Squares (WLS) is used to estimate oil and gas production for all of the individually reported states/areas in the Monthly Crude Oil, Lease Condensate, and Natural Gas Production Report (EIA-914). The particular model used is a single regressor linear model with the weights equal to the inverse of the regressor, i.e. the Classical Ratio Estimator (CRE).¹¹ Past work has shown this to be a robust and 'natural' estimator with a wide variety of applications. The model is structured as:

Equation 1

$$y_i = \beta x_i + e_i$$

Where ' y_i ' is the survey reported production rate of operator ' i ', ' x_i ' is the average production rate from the DI dataset of operator ' i ' over a six month time period, and e_i is a random disturbance with mean 0 and variance $x_i\sigma^2$. The particular six month period used to determine ' x_i ' is described below in the section "Lag Times." If operators $i=1$ through $i=n$ are sampled, and operators $i=n+1$ through $i=N$ are unsampled, then the WLS estimate of β is:

¹¹ For a review, see ["The Classical Ratio Estimator"](#) by James R. Knaub, published on InterStat, 2005.

$$\beta = \frac{\sum_{i=1}^n y_i}{\sum_{i=1}^n x_i}$$

And the estimate of the total production for a state is equal to:

$$\hat{T} = \frac{\sum_{i=1}^N x_i \sum_{i=1}^n y_i}{\sum_{i=1}^n x_i}$$

The difference between this estimate of the total and the true total has expected value 0 and variance equal to:

Equation 2¹²

$$V(T - \hat{T}) = \sigma^2 \left(\sum_{i=n+1}^N x_i + \frac{(\sum_{i=n+1}^N x_i)^2}{\sum_{i=1}^N x_i} \right)$$

The Standard Error described in the section “Potential Sources of Errors” is the square root of this variance. The estimator for σ^2 is:

$$\hat{\sigma}^2 = \frac{1}{n-1} \sum_{i=1}^n \frac{(y_i - \hat{y}_i)^2}{x_i}$$

Each month an estimate for the current month and the previous two months is generated using each month’s sample reported volumes and the latest DI database, revising the previous two month estimates.

Lag times

As described above, the ‘ x_i ’ used in the estimation routine is a six month average production rate from the DI dataset. The DI dataset contains all the data that DI has been able to acquire and process. The data are released as they become available, and so are not released on the same schedule. Some states report their data faster than others, and similarly some operators report their data faster. In addition, revisions to the data are common for recently submitted data. As a result of these considerations, EIA calculates a ‘most recently complete month’ for each state in the DI dataset. The methodology for this calculation is the same as Step 1 of the ALR method as described in EIA’s [methodology](#) for crude oil production estimates. Briefly, the methodology calculates the number of months between the report month and the month at which the state total production volume is anticipated to be within half a percent of its final value. The ‘ x_i ’ are based on the most recent month with complete data and the five months previous to it. Typical lags are given in table 1, but may be adjusted occasionally depending on changing circumstances. For states that only report annually it is necessary to adjust their lag each month.

¹² Found in “[Projected Variance for the Model-Based Classical Ratio Estimator](#)” by James R. Knaub, published on InterStat.

Table 1. State lags, September 2015

State	Oil Lags (number of months)	Gas Lags (number of months)
Arkansas	3	3
California	4	5
Colorado	13	13
Federal Gulf of Mexico	6	5
Kansas	5	5
Louisiana	4	4
Montana	5	5
New Mexico	5	5
North Dakota	6	6
Ohio	9	9
Oklahoma	11	16
Pennsylvania	9	9
Texas	5	9
Utah	5	5
West Virginia	9	9
Wyoming	9	5

Ohio, Pennsylvania, and West Virginia report their data annually. For these states, the lag is set to place the most recently complete month on December of the most recently reported year.

Other states ratio

For the other states, the ratio of total state reported data to the EIA-914 reported data is calculated based on calendar year volumes and is multiplied by the current month's EIA-914 reported volume to determine the estimate. State production data for the other states are collected directly from the states,¹³ and also may be incomplete in recent months just as the state data from DI often are for individually sampled states. As mentioned earlier, complete production for some of the other states may not be available. Therefore, the estimate for the other states may be lower than an estimate based on complete production data for other states. Because one year of reported EIA-914 data will not be available until 2016, an estimated startup ratio is determined based on historical state data from DI and state data for both oil and gas. Until 2015 calendar year EIA-914 reported data are collected the startup ratio will be used.

¹³ EIA analysts and contractors visit state websites and correspond with state officials to acquire the most recently available production data of those states.

Because EIA will continue publishing oil production estimates for all states individually, including states in the other states category, EIA uses its previous oil production estimation methodology that is based on the EIA-182 (Domestic Crude Oil First Purchase Report) data and lagged state reported data as the official other states oil production estimation method.¹⁴ (This is the ALR method¹⁵ mentioned earlier.) The oil production estimate described in the paragraph above is used for comparative analysis of the individual state oil production estimates provided by the ALR method. The other states category accounts for roughly 3 percent of the total lower 48 states production for both oil and gas.

Estimates of natural gas lease production and oil sales by API gravity

The EIA-914 collects production data for two separate gas volumes: gas gross withdrawals and lease gas production. Natural gas gross withdrawals are generally gas production measured after lease separation. Natural gas lease production is generally gas that comes off the lease or gas sales. The difference between the two accounts for gas that is used on the lease for fuel, vented and flared, injected, and the removal of non-hydrocarbon gases. Lease production is used to determine EIA's estimates of dry gas production. The WLS model is used to estimate gross withdrawals, and the ratio of estimated total to sampled gross withdrawals is multiplied by sampled lease production to estimate lease production.

The EIA-914 collects production data for two separate oil volumes: oil production and oil sales by API gravity category.¹⁶ In order to estimate state production by API category, it is assumed that state production has the same proportional distribution of API categories as the reported API category volumes. That is, the reported distribution of API gravity volumes (including the unknown category) is applied to the estimated total production volume to estimate the total API gravity volumes. Although EIA collects API gravity for 10 categories, including "unknown," the categories are collapsed into four categories for the reporting of state-level API gravity estimates. Many categories at the state level have too few respondents to be reported separately because of confidentiality rules. Suppression of these under-reported categories was accomplished by collapsing categories. For example, the 40.1-45.0 category and the 45.1-50.0 category were combined to create a 40.1-50.0 category. Suppression of these under-reported categories was accomplished by collapsing categories. Further, the state-level volumes reported in the "unknown" category are allocated to the individual categories rather than reported separately.

Potential sources of errors

Alignment of survey and DI datasets

Unknown, deficient reporting of, or incorrectly handled mergers and property sales are likely the largest cause of errors. These events may occur every month, making the alignment of the survey and DI datasets a continuous and critical task. The company production in the historical DI dataset must be matched to the reported sample data every month. If an operator in one dataset corresponds to different properties than in the other, the modeled relationship between 'yi' and 'xi' is invalid. The

¹⁴ An asymmetry in the estimation of gas production for Other States exists because no EIA survey collects state-level gas sales volumes aside from Form EIA-914. Alternatively Form EIA-182 collects oil sales volumes, which may be used to estimate Other State oil production.

¹⁵ The ALR methodology can be found at <http://www.eia.gov/petroleum/supply/monthly/pdf/crudemeth.pdf>.

¹⁶ Respondent companies are allowed to report production or sales volumes by API gravity category on Form EIA-914. However, it is expected that sales are predominately reported in the API gravity portion of the survey (Part 4).

unknown or missed events are usually small and do not contribute to significant large errors, but it is still possible to miss a larger event. In addition to mergers, sales, and acquisitions, the following are examples of items that can contribute to errors in the alignment of survey data with state data from DI: name changes, multiple name spellings, companies that report under multiple names, and lags between the time of a merger and the time of its appearance in the DI dataset. In practice, these misalignments result in a larger estimated RSE (see below), and so are partially accounted for under ‘sampling error.’

Frame coverage

If the sampling frame (state data from DI) does not include all of the operators in a state, then part of the population will be missing in both sampling and estimation, and estimates will be low. This is frame coverage error. In some states, such as the previously mentioned Illinois, Indiana, Kentucky, and Tennessee, the state data from DI are known to be missing or incomplete, and so another method is used to estimate these states, described in the Estimation Methodology below. In other states with long time lags (in which the most recent state data from DI may be more than a year old) frame coverage becomes a concern, as well, since new operators may exist that are not in the frame. EIA attempts to identify and resolve such errors through the use of additional data sources such as State reports and publications.

Reporting errors

Reporting errors such as incorrect units or incomplete or otherwise incorrect accounting can occur on the EIA-914. The survey instrument itself was carefully developed and includes detailed instructions for filing data, subject to a common set of definitions similar to those already used by the industry. Editing software has been developed to detect different kinds of probable reporting errors and to flag them for resolution by analysts, either through confirmation of the data by the respondent or through submission of amendments to the filed data (see the section “Data Quality Control Checks”).

Model failure

Both experience and experiment show that the model in Equation 1 holds very well. However, very dynamic events can cause the population to behave abnormally and, particularly when combined with long time lags in the state data from DI, the model may deviate from reality. For example, the rapid development of the Haynesville shale in Louisiana caused a change in the State production trend that, in turn, caused the method to overestimate for a short time late in the 2000s. EIA attempts to identify regions that may be likely to behave in such a way, and if the deviations were to become substantial a change to the estimation methodology, such as a stratification, would have to be made. As an additional safeguard against model failure, EIA targets sample coverage of 85 percent in all states, so that the effects of model failure would be minimized.

Sampling error

Sampling error may be defined as the difference between the estimates obtained from a sample and the results that would have been obtained from a complete enumeration of the frame population. The standard error statistic is a measure of this sampling error, and is the square root of the quantity given in Equation 2. When presented as a percentage of the estimated total, it is called the relative standard error (RSE). The sampling methodology described in this report has yielded RSE’s of the following magnitudes for the first three months of gas collection.

Table 2. RSEs for first three months of estimates, 2015

State	January	February	March
Arkansas	0.12%	0.14%	0.11%
California	1.94%	1.99%	2.18%
Colorado	1.20%	1.21%	1.24%
Federal Gulf of Mexico	0.51%	0.57%	0.74%
Kansas	0.90%	0.92%	1.01%
Louisiana	0.45%	0.44%	0.56%
Montana	3.40%	3.30%	3.52%
New Mexico	0.37%	0.26%	0.45%
North Dakota	0.57%	0.61%	0.92%
Ohio	4.02%	4.38%	4.78%
Oklahoma	3.13%	2.85%	2.77%
Other states	-	-	-
Pennsylvania	2.78%	2.79%	2.59%
Texas	1.86%	1.30%	0.45%
Utah	0.47%	0.94%	0.61%
West Virginia	11.60%	10.27%	9.59%
Wyoming	7.25%	3.22%	5.34%

Note that RSEs are not calculated for the other states region, which uses a different estimation methodology. Also note the large RSEs in West Virginia. This is a result of the long time lag in West Virginia, and indicates that frame coverage is a concern for this state. West Virginia has published a preliminary report of 2014 production data that EIA is investigating to solve this problem. Oil data are still being cleaned and associated estimates have unacceptable RSEs in many states, and they are not presented in this document.

Replacement of estimates with state data

Given the revision schedule of the natural gas and oil production estimates (i.e., each month data are released for the current month and revised for the two previous months), once a year the estimates for the two previous years are replaced with final state data. The timing of the revisions/replacement of estimates with state data is with the publication of the *Natural Gas Annual* (NGA) for natural gas production estimates and the publication of the *Petroleum Supply Annual* (PSA) for oil production estimates. The NGA is normally published each October while the PSA is normally published each August.

Data quality control checks

EIA employs automated systems to identify suspect data submissions. The initial set of checks tests the submitted data. Once the suspect data submissions are identified many additional efforts are made to further identify and correct errors in submitted data. Follow up with respondents via personal communication and research is carried out when a data discrepancy is identified. Reported production data are compared with state production data from DI for each sampled company to ensure the

companies are correctly identified and matched. Company reported data may also be compared with their state-reported data to assure correct reporting. Mergers and property acquisitions reported in trade press and other media are tracked and companies are routinely contacted to ensure complete accounting without double counting or under reporting production. Companies are also contacted if an unusual or large change in a company's production is reported without explanation. Production estimates are continuously compared to state reported production to check for significant differences.

Outlier process

Some responses from respondent companies are far outside the anticipated value. For example, a company may have extreme growth or decline in recent months. Evaluations of these atypical responses are made and, if, in the opinion of the data analysts and the survey manager, these responses are excessively affecting the survey results, then they may be omitted from the normal estimation process, but added-in later in the process.

Imputation

Company nonresponse occurs from time to time, and occasionally, a company may report a value that is out of the expected range. Omitted submissions, incomplete submissions, and unexplained submitted values that considerably deviate from historically submitted values may require an imputation. Typically, efforts to collect accurate data from nonrespondent companies continue until they submit their data. However, if missing data or suspicious data cannot be acquired from the company or satisfactorily explained by the company, data are imputed at the time of estimation. For natural gas production and sales, and oil production, imputed values are derived by using a three-month average of the most recently available data.

If the company has been a respondent company for at least three months, then the company's historic EIA-914 values are used. In the absence of sufficient 914 company data, data from DI are used to calculate the imputed values.

Oil sales volumes (oil volumes by API gravity category) may be imputed if the data are missing, incomplete, or the distribution of submitted data across the API gravity categories deviates considerably from those historically submitted by the respondent company. The imputed volumes are calculated using the weighted-average distribution from the previous three months. Every effort is made to obtain accurate data from the respondent before using an imputed value.

On rare occasions, weather events, pipeline disruptions, plant outages, or other unusual events occur that may prevent standard imputation methods from providing reasonable values. In this situation, EIA's expert analysts will determine an imputed value based on industry knowledge, weather data, information from respondents, trade press and news reports, information from state and federal agencies, past performance, and expert judgement.

Suppression

EIA employs statistical disclosure limitation techniques to preserve the confidentiality of the information collected on the EIA-914. The p-percent rule is applied to the statistical aggregates.

Coverage and Response Rate

Coverage and Response Rates are published to give some insight to the quality of the data collection and processing. Coverage is determined by dividing the reported values by the estimated values for each state. Response rate is calculated as the volume reported by companies responding to the survey divided by the volume of reporting companies plus the expected volume for non-reporting companies.