Summary and Analysis of the 2011-2016 Gasoline Sulfur Compliance Reports

United States Environmental Protection Agency

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Compliance Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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United States Environmental Protection Agency

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List of Acronyms

ABT	Averaging, Banking, and Trading
ASTM	American Society for Testing and Materials
CBOB	Conventional Blendstock for Oxygenate Blending
CFR	Code of Federal Regulations
CG	Conventional Gasoline
EMTS	EPA Moderated Transaction System
EPA	United States Environmental Protection Agency
PADD	Petroleum Administration for Defense District
ppm	Parts per Million
RBOB	Reformulated Blendstock for Oxygenate Blending
RFG	Reformulated Gasoline
GSF0100	Gasoline sulfur credit averaging, banking and trading (ABT) report
GSF0200	Gasoline sulfur credit transfer report
GSF030X	Gasoline sulfur facility summary report
RFG030X	Batch report for RFG and CG
GSF0401	Gasoline sulfur supplementary batch report

I. Executive Summary

Beginning in 2004, the United States Environmental Protection Agency ("EPA" or "the Agency") set standards limiting the amount of sulfur in gasoline to help reduce vehicle emissions, and protect emission controls in vehicles and engines.[1] The Tier 2 gasoline sulfur program established standards beginning January 1, 2004, which phased down gasoline sulfur over a seven-year period. Under this program, all gasoline produced in or imported into the United States was required to meet an annual average sulfur standard of 30 parts per million ("ppm") beginning January 1, 2011, and also meet a maximum per-gallon standard of 80 ppm sulfur. The program allowed refiners and importers to generate gasoline sulfur credits by producing or importing gasoline containing less than 30 ppm sulfur on an annual average basis. These credits could be used by refiners and importers which produced or imported gasoline containing more than 30 ppm sulfur on an annual average basis. Credits could be "banked" for use in future years, and expired if not used within five years after the year of generation.

The Tier 3 gasoline sulfur program further reduced gasoline sulfur so that all gasoline produced or imported in the United States will meet an annual average sulfur standard of 10 ppm. The Tier 3 standards began on January 1, 2017 and will be fully phased in beginning January 1, 2020. Similar to Tier 2, the Tier 3 program also provides refiners and importers the flexibility to generate and use credits in complying with the 10 ppm average standard.

The purpose of this report is to provide an explanation of how refiners and importers complied with the 30 ppm annual average sulfur standard from 2011 through 2016. This period of time covers the first six years during which the 30 ppm Tier 2 sulfur standard was fully phased in, and also covers a five-year period (January 1, 2012 through December 31, 2016) during which refiners and importers had an opportunity to generate "early" Tier 3 credits for compliance with the 10 ppm average sulfur standard.

The data in this report were aggregated from compliance data reported to the EPA by gasoline refiners and importers. Key findings include:

- The reported national average gasoline sulfur content of gasoline decreased from 31 ppm in 2011 to 24 ppm in 2016. This downward trend is expected to continue as the Tier 3 sulfur standards began to phase in starting January 1, 2017.
- The percentage of gasoline produced or imported at facilities averaging 30 ppm sulfur or less on an annual basis increased from 47 percent in 2011 to 81 percent in 2016.
- In 2011 and 2012, refiners and importers used more credits than they generated, due to use of some credits that were generated before 2011. From 2013 to 2016 refiners and importers generated more credits than they used.

[1] In order to protect emission controls, a 1977 amendment to the Clean Air Act required unleaded gasoline in commerce to be "substantially similar" to the unleaded gasoline used in certifying vehicles to emission standards. In an interpretive rule, the Agency defined "substantially similar," including compliance with the ASTM standard which limited sulfur in unleaded gasoline to 1000 ppm. The rule also limited an additive's sulfur contribution to unleaded gasoline to 15 ppm.

- Refiners have used progressively fewer credits to achieve compliance with the 30 ppm annual average sulfur standard from 2011 through 2016.
- Refiners appear to have generated a large number of “early” Tier 3 sulfur credits between 2013 and 2016 in anticipation of complying with the 10 ppm annual average sulfur standard beginning in 2017.
- From 2011 through 2016, compliance by refiners and importers with the 80 ppm per gallon standard was very close to 100 percent.

II. Background on Gasoline Sulfur Programs

A. Tier 2 Gasoline Sulfur Program

1. Overview

Beginning in 2004, refiners and importers were subject to gasoline sulfur standards established in the "Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements" ("Tier 2 rule"). The EPA finalized the Tier 2 rule on February 10, 2000, including gasoline sulfur requirements promulgated in 40 CFR Part 80, Subpart H. [2, 3] The purpose of these gasoline sulfur requirements was to reduce the sulfur concentration of all gasoline sold in the United States from approximately 300 ppm to an average of 30 ppm, in order to enable emissions control equipment on new vehicles to significantly reduce emissions of pollutants, such as nitrogen oxides and volatile organic compounds, as well as to provide public health and welfare benefits. The Tier 2 gasoline sulfur regulations achieved this reduction by establishing a series of annual sulfur standards that gradually decreased allowable sulfur concentrations so that by 2011, all refiners and importers had to meet an annual average sulfur standard of 30 ppm, and a per-gallon sulfur standard of 80 ppm.[4]

Gasoline refiners and importers could meet the annual average sulfur standard by either of two ways:

1) Producing or importing gasoline with an annual average sulfur content less than or equal to the 30 ppm average standard; or,
2) Producing or importing gasoline with an annual average sulfur content greater than the 30 ppm average standard, and using credits to meet the standard (more discussion below on credits).

The 80 ppm per-gallon sulfur standard had to be met directly; credits could not be used to meet the 80 ppm per-gallon standard.

2. Averaging, Banking and Trading (ABT) Program for Gasoline Sulfur Credits

Refiners and importers could generate gasoline sulfur credits (in ppm-gallons) on a refinery-specific or Petroleum Administration for Defense District (PADD) basis, respectively. Beginning in 2004, most refiners and all importers could generate credits for each year by producing gasoline with an annual average sulfur content less than 30 ppm, according to the formula "(30 – annual average sulfur) X total annual gasoline volume".[5] Beginning in 2011, all refiners and importers could generate credits using this formula. Credits could be used for

[2] See 65 FR 6697, February 10, 2000.
[3] More information on the Tier 2 and Tier 3 gasoline sulfur programs can be found at the EPA's website at https://www.epa.gov/gasoline-standards/gasoline-sulfur.
[4] All gasoline downstream of refineries and import facilities had to meet a per-gallon standard of 95 ppm sulfur.
[5] From 2004 through 2010, some refineries had annual average standards that were greater than 30 ppm, and could generate credits by producing gasoline with an annual average sulfur content less than their specific standard, see 40 CFR 80.310.

compliance up to five years after the year that they were generated, and could be transferred no more than twice between refiners and/or importers. Credits expired if unused after five years.

3. California Gasoline

Gasoline produced or imported for use in California ("California gasoline") was exempt from all of the requirements in 40 CFR Part 80, Subpart H, provided it met certain requirements specified in 40 CFR 80.375. As a result, no California gasoline was reported to the EPA under the Tier 2 rule, and all volume and property data shown in this report does not include California gasoline.[6]

4. Oxygenate Blending and Accounting

Similar to Subparts D (Reformulated Gasoline) and E (antidumping) of 40 CFR Part 80, Subpart H also allowed refiners and importers to include downstream-blended oxygenate (typically ethanol) in their gasoline sulfur compliance calculations if they complied with the requirements in 40 CFR 80.69(a) or 80.101(d)(4).[7] Refiners and importers generally met the oversight program requirement in 40 CFR 80.69(a)(11) for downstream blending of oxygenate in reformulated blendstock for oxygenate blending ("RBOB"), by participating in the RFG Survey Association, and used the sulfur test result from their hand blend of RBOB and oxygenate per 40 CFR 80.69(a)(2) in their gasoline sulfur compliance calculations.[8] For downstream blending of oxygenate in CG or conventional blendstock for oxygenate blending ("CBOB"), refiners and importers met the oversight program requirement in 40 CFR 80.101(d)(4)(ii) on an individual basis. Refiners and importers that met the oversight program requirement in 40 CFR 80.101(d)(4)(ii) could assume that oxygenate blended into their conventional gasoline or CBOB contained no sulfur.[9] Oxygenate blenders (i.e., downstream parties that simply blended oxygenate into RBOB, CBOB, or CG) were only required to ensure that any ethanol they blended into RBOB, CBOB or CG contained less than 30 ppm sulfur. Tables 1 through 3 provide data on total volumes of ethanol in gasoline (not including California gasoline) from 2011 through 2016, based on reports submitted by refiners and importers to EPA.[10]

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[6] California gasoline is also excluded from reports submitted by refiners and importers under 40 CFR Part 80, Subparts D (RFG) and E (antidumping), per 40 CFR 80.81.

[7] Refiners and importers benefit from including ethanol in their gasoline sulfur compliance calculations because of ethanol's low sulfur content. The provisions in 40 CFR 80.69(a) and 80.101(d)(4) required refiners and importers to verify their included volumes of downstream-blended oxygenate through a combination of product transfer documents, contractual arrangements with oxygenate blenders, and periodic sampling and testing of oxygenate-blended gasoline.

[8] RBOB is a gasoline blendstock that becomes RFG upon blending with a specified type of oxygenate, typically ethanol. In order to comply with the RFG standards in Subpart D, refiners and importers of RBOB prepare a "hand blend" sample of RFG by blending a batch sample of RBOB with a refiner-specified percentage of ethanol, and test the RBOB/ethanol blend for several properties, including sulfur, per 40 CFR 80.69(a)(2). The refiner-specified percentage of ethanol is transmitted on the product transfer document for the RBOB to a downstream oxygenate blender, who blends the RBOB batch with the specified percentage of ethanol.

[9] CBOB is a blendstock that becomes conventional gasoline upon blending with a specific type of oxygenate.

[10] Gasoline volumes and ethanol concentrations were taken from the RFG030X reports. Volumes of ethanol in RFG, CG, and (RFG+CG) were calculated by multiplying the corresponding gasoline volumes and ethanol concentrations.

Table 1: Annual RFG Volumes, Ethanol Concentrations, and Ethanol Volume in RFG

Year	Total RFG, million gallons	Ethanol in RFG, volume percent	Ethanol in RFG, million gallons
2011	30,974.0	9.63	2,982.4
2012	30,495.1	9.59	2,925.3
2013	30,758.4	9.61	2,956.1
2014	31,315.9	9.63	3,014.8
2015	32,194.2	9.64	3,104.6
2016	33,321.5	9.66	3,218.5

Table 2: Annual CG Volumes, Ethanol Concentrations, and Ethanol Volume in CG

Year	Total CG, million gallons	Ethanol in CG, volume percent	Ethanol in CG, million gallons
2011	84,305.6	2.08	1,751.8
2012	84,512.6	2.08	1,757.9
2013	84,354.7	2.06	1,738.3
2014	85,140.2	2.30	1,956.4
2015	87,169.6	2.40	2,096.3
2016	89,283.4	2.39	2,130.6

Table 3: Annual (RFG+CG) Volumes, Ethanol Concentrations, and Ethanol Volume in (RFG+CG)

Year	Total (RFG+CG), million gallons	Ethanol in (RFG+CG), volume percent	Ethanol in (RFG+CG), million gallons
2011	115,279.6	4.11	4,734.2
2012	115,007.7	4.07	4,683.2
2013	115,113.1	4.08	4,694.3
2014	116,456.1	4.27	4,971.2
2015	119,363.8	4.36	5,200.9
2016	122,604.9	4.36	5,349.1

B. Tier 3 Gasoline Sulfur Program

The EPA finalized the "Tier 3 Motor Vehicle Emission and Fuel Standards" rulemaking ("Tier 3 rule") on April 28, 2014, including gasoline sulfur requirements promulgated in 40 CFR Part 80, Subpart O.[11] The purpose of the Tier 3 rule was to further reduce the sulfur concentration of all gasoline sold in the United States from an average of 30 ppm to an average of 10 ppm. This enabled emissions control equipment on new vehicles to further reduce

[11] Additional information on the Tier 3 rule can be found on the EPA website at https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3.

emissions of pollutants, such as nitrogen oxides and volatile organic compounds, providing significant benefits to public health and welfare. The Tier 3 gasoline sulfur regulations required most refiners and all importers to meet an annual average standard of 10 ppm sulfur beginning January 1, 2017.[12] Consequently, Tier 3 data was not yet available for analysis during the development of this report. However, this report does include data that captures actions by refiners and importers leading up to the start of the Tier 3 program, in particular the ABT provisions discussed below.

The Tier 3 rule has many similarities to the Tier 2 rule. The 10 ppm average standard in the Tier 3 rule applies to each refinery's annual gasoline production, and each importer's annual gasoline importation on a PADD basis.[13] Refiners and importers continue to be subject to a per-gallon sulfur standard of 80 ppm, and all gasoline continues to be subject to a downstream per-gallon standard of 95 ppm. The Tier 3 gasoline sulfur regulations also include an ABT program for gasoline sulfur credits that allows refiners and importers to generate credits (in ppm-gallons) and use them to comply with the 10 ppm average standard. Beginning January 1, 2017, sulfur credits are generated by producing or importing gasoline containing an annual average sulfur of less than 10 ppm. These credits have a life of five years after the year of generation (i.e., 2017 credits expire if not used after the 2022 compliance period), and may be banked by the refiner that generated them, or sold to another refiner for use in complying with the 10 ppm standard.

Additionally, the Tier 3 rule allows refiners and importers to use Tier 2 gasoline sulfur credits generated from 2012 through 2016 for compliance with the 10 ppm average sulfur standard from 2017 through 2019.[14] From 2012 through 2016, refiners and importers could generate gasoline sulfur credits for use in meeting either the 30 ppm average sulfur standard through 2016, or for use in meeting the 10 ppm average sulfur standard from 2017 through 2019. Individual credits could be used to meet either the 30 ppm or 10 ppm average standard, but the same credits could not be used to meet both standards (see example in the Appendix of credit generation and use under the Tier 2 and Tier 3 programs). These credits have a maximum life of five years after the year of generation (i.e., 2012 credits expire if not used after the 2017 compliance period), and all expire if not used by the 2019 compliance period.

III. Gasoline Sulfur Compliance Analysis from 2011 through 2016

A. Summary

This report presents analyses of data, primarily from the gasoline sulfur reports, from 2011 through 2016. The data is reported to the EPA on various reporting forms by refiners and importers on an annual basis for all gasoline they produce for use in the U.S. outside of California. Thus, the report provides a comprehensive summary of gasoline sulfur

[12] Small refiners and small volume refineries could continue complying with the 30 ppm sulfur standard through December 31, 2019, see 40 CFR 80.1603(a)(1)(iii)(B).
[13] Additional information on PADDs can be found on EIA's website at https://www.eia.gov/todayinenergy/detail.php?id=4890.
[15] The GSF0200 form has been superseded by EPA's Moderated Transaction System (EMTS), which allows refiners and importers to report credit transactions online.

concentrations, and gasoline sulfur credit generation and use for all gasoline reported to EPA from 2011 through 2016.

Under the pre-existing RFG and antidumping programs, refiners and importers were required to report several properties, including sulfur, for each batch of gasoline on the EPA batch report form RFG0300. In addition to the RFG and antidumping gasoline batch report form, the EPA created four new reporting forms for refiners and importers to report data for the Tier 2 program. These five forms are listed below, along with a description of each form's purpose under Tier 2.

1) Gasoline Sulfur Credit Banking and Allotment Generation Report (GSF0100)
   - Refiners and importers report total annual gasoline sulfur credit generation, use, transfers, and expiration by facility (credit units are ppm-gallons)
   - All information is reported separately by credit creation year
2) Gasoline Sulfur Credit Transfer/Conversion Report (GSF0200) [15]
   - Refiners and importers report each transfer of credits to or from another party
   - Reported information includes credit quantity, transfer date, company and facility IDs for the buyer and seller, credit type, and credit creation year
3) Gasoline Sulfur Facility Summary Report (GSF0300)[16]
   - Refiners and importers report their total annual gasoline production, average sulfur before using credits, and average sulfur after using credits (if applicable) by facility
   - Demonstrates compliance with the 30 ppm annual average sulfur standard
4) Reformulated Gasoline and Anti-Dumping Batch Report (RFG0300) [17]
   - Refiners and importers report all complex model properties (including sulfur) for each batch of gasoline
   - Demonstrates compliance with the 80 ppm per-gallon sulfur standard, except for CG batches that are composited
5) Gasoline Sulfur and Benzene Batch Report (GSF0401)
   - Supplementary report used by refineries or importers which report properties for composited batches of CBOB and/or CG on the RFG0300 report[18]
   - Refiners and importers must report the volume and sulfur content of each sub-batch of CBOB and/or CG used to form the composite batch, in order to demonstrate compliance with the 80 ppm per-gallon standard for each sub-batch

The analysis contained in this report begins with 2011, the first year that the EPA has complete sets of the primary reports (GSF030X reports and GSF0100 reports) fully uploaded to

[15] The GSF0200 form has been superseded by EPA's Moderated Transaction System (EMTS), which allows refiners and importers to report credit transactions online.
[16] The GSF0300 reporting form was revised and was subsequently re-issued as the GSF0301 reporting form. In this report, both forms will be collectively referred to as the GSF030X reports.
[17] The RFG0300 reporting form was subsequently revised and re-issued 3 times as the RFG0301, RFG0302 and RFG0303 reporting forms, respectively. In this report, these 4 reporting forms will be collectively referred to as the RFG030X reports.
[18] 40 CFR Part 80, Subpart E (antidumping) allows refiners and importers to test a single composite sample prepared from all of the gasoline they produce or import for a period of up to one month, per 40 CFR 80.101(i)(2).

its electronic database in a format suitable for analysis.[19] This was also the first year in which all refiners and importers had to comply with the 30 ppm annual average sulfur standard, since all provisions for delayed Tier 2 compliance by small refiners and hardship refiners ended December 31, 2010. The industry compliance trends reported here reflect, to a large extent, the ABT provisions which are a part of both the Tier 2 and Tier 3 gasoline sulfur regulations.

Data in this report does not include any volume or property data for California gasoline, and includes only a portion of the total amount of ethanol that is actually blended into CG and CBOB at locations downstream of refineries and import facilities. Gasoline produced or imported for use in California is not reported to the EPA, under certain reporting exemptions in the EPA regulations. Also, refiners and importers calculate their total gasoline volume and average sulfur using only a portion of the total ethanol that is actually blended at downstream locations into their CG and CBOB, due to certain compliance requirements in the EPA regulations.[20] Lastly, butane and pentane that were blended into gasoline under the EPA's simplified compliance requirements are included in the GSF030X report data, but not in the GSF0100 report data, since butane blenders and pentane blenders may not generate gasoline sulfur credits.

In this report, the term "facilities" is generally used to describe all facilities that produce or import gasoline. These include refineries that produce gasoline by refining crude oil, and other facilities ("blender-refineries") that produce gasoline simply by combining gasoline blendstocks obtained from other refineries. [21] In the analysis section below, the number of crude oil refineries in the facility counts varies from 107 to 112.[22] The number of blender-refineries in the EPA's facility count varies from 204 to 308.[23] Lastly, the number of import facilities varies from 26 to 42, where all of an importer's import locations in one PADD are typically reported as a single facility (e.g., an importer that imported gasoline into five different locations in PADD 1 would report the total volume of imported gasoline under a single "PADD 1" import facility).

B. Analysis

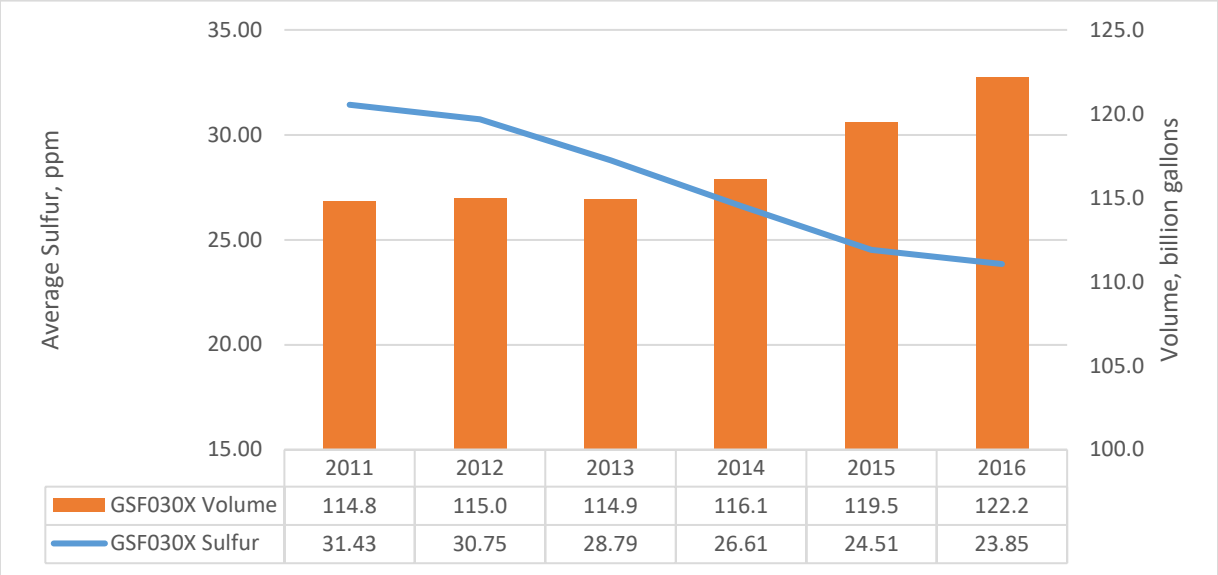
1. Compliance with 30 ppm Annual Average Sulfur Standard

Gasoline sulfur concentrations trended down from 2011 through 2016, as shown in Figure 1. Annual average sulfur exceeded 30 ppm in 2011 and 2012, as refiners and importers

[19] The EPA has many GSF030X and GSF0100 reports that were submitted prior to 2011 in a variety of formats, including paper, diskettes and compact disks, which must be manually loaded into its database. The EPA is in the process of loading these reports from 2010 and earlier into its database, for use in additional analysis.
[20] See Tables 1 through 3.
[21] The EPA defines a refinery as "any facility, including but not limited to, a plant, tanker truck, or vessel where gasoline or diesel fuel is produced, including any facility at which blendstocks are combined to produce gasoline or diesel fuel, or at which blendstock is added to gasoline or diesel fuel". See 40 CFR 80.2(h).
[22] The number of crude oil refineries was determined by comparing the list of reporting facilities with the annual lists of refineries with crude distillation units, prepared by the U.S. Energy Information Administration as part of its annual refinery capacity reports.
[23] The number of blender-refineries was calculated by subtracting the number of crude oil refineries and import facilities from the total number of reporting facilities. Blender-refineries include a small number (between 5 and 8) of transmix processing facilities which distill transmix (i.e., pipeline interfaces of gasoline and distillate fuel) into gasoline and distillate, and sometimes add other blendstocks to the gasoline distilled from the transmix.

used credits generated in previous years to comply with the 30 ppm standard.[24] Annual average sulfur dropped below 30 ppm in 2012, and continued to decrease through 2016, possibly due to refiners and importers generating and banking credits for use in complying with Tier 3's 10 ppm annual average sulfur standard beginning in 2017.

Figure 1: Total Gasoline Volume and Average Sulfur from GSF030X Reports

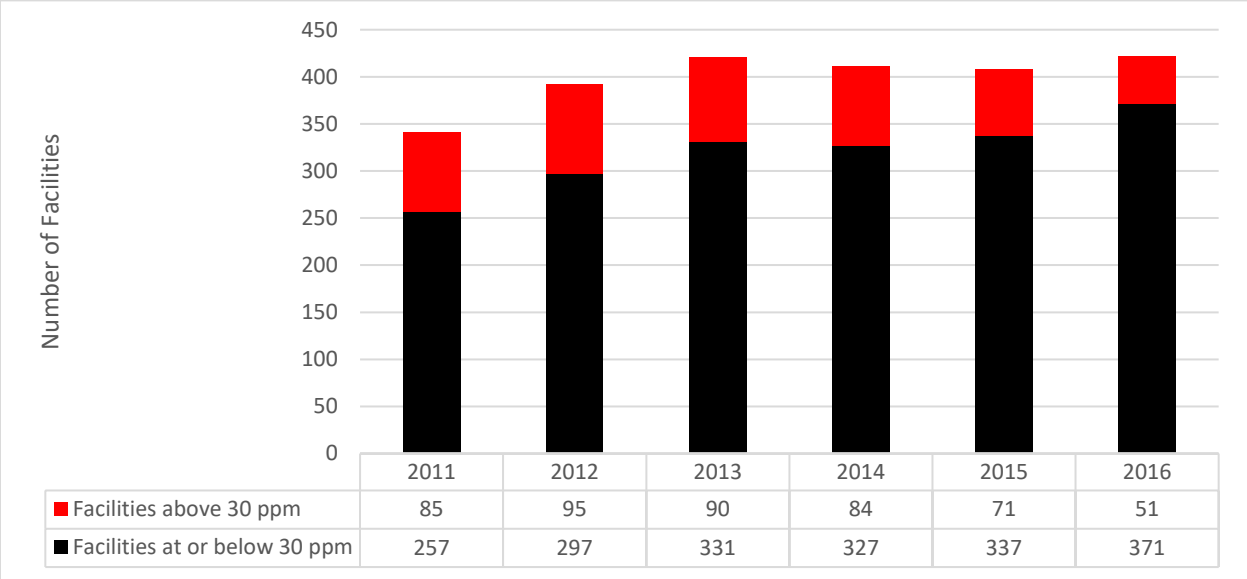


	2011	2012	2013	2014	2015	2016
GSF030X Volume	114.8	115.0	114.9	116.1	119.5	122.2
GSF030X Sulfur	31.43	30.75	28.79	26.61	24.51	23.85

Figure 2 shows the number of facilities producing gasoline averaging over 30 ppm sulfur on an annual basis, and the number of facilities producing gasoline averaging 30 ppm or less on an annual basis, from 2011 through 2016. The number of facilities using credits decreased by 34 from 2011 through 2016, and the number of facilities generating or not needing credits increased by 114, consistent with the decrease in annual average sulfur content shown in Figure 2.

[24] Refiners and importers reported on their 2011 GSF0100 reports that they held a total of 2,500 billion gasoline sulfur credits as of January 1, 2011.

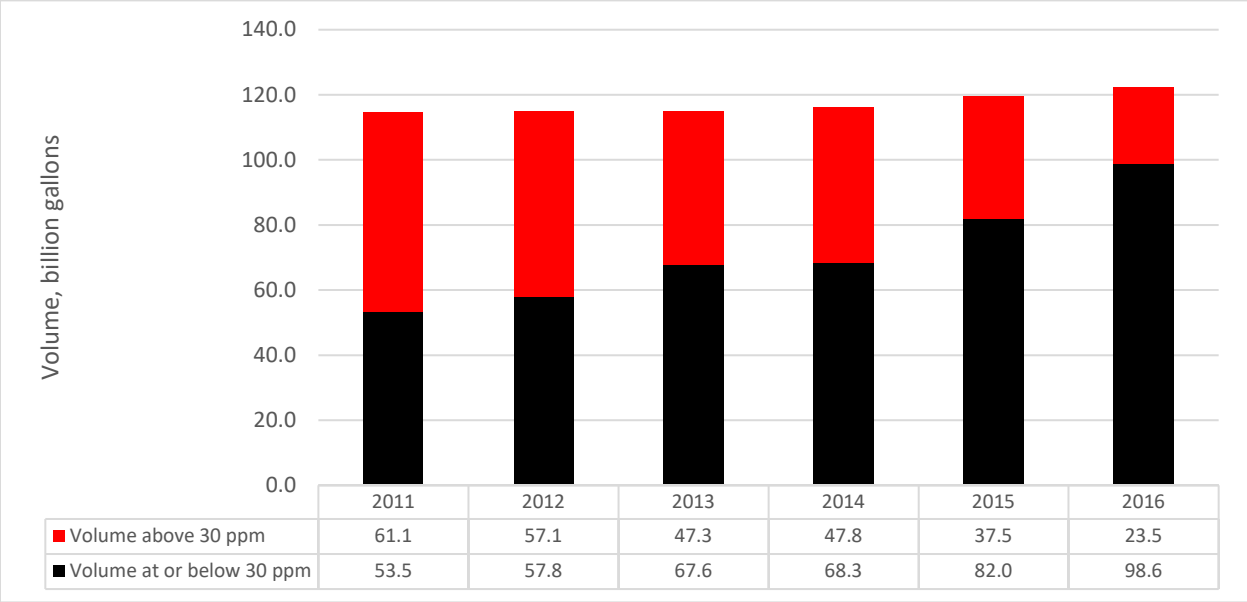
Figure 2: Facilities Producing Gasoline with Annual Average Sulfur Above/Below 30 ppm (pre-credits)



	2011	2012	2013	2014	2015	2016
Facilities above 30 ppm	85	95	90	84	71	51
Facilities at or below 30 ppm	257	297	331	327	337	371

Figure 3 shows the volume of gasoline produced by facilities that averaged over 30 ppm sulfur on an annual basis, and the volume of gasoline produced by facilities that averaged 30 ppm sulfur or less on an annual average basis, from 2011 through 2016. From 2011 through 2016, the volume of gasoline produced at facilities that averaged 30 ppm sulfur or less increased by approximately 45.1 billion gallons, and the volume of gasoline produced at facilities that averaged over 30 ppm sulfur decreased by approximately 37.6 billion gallons.

Figure 3: Volume of Gasoline Produced at Facilities with Annual Average Sulfur Above/Below 30 ppm (pre-credits)

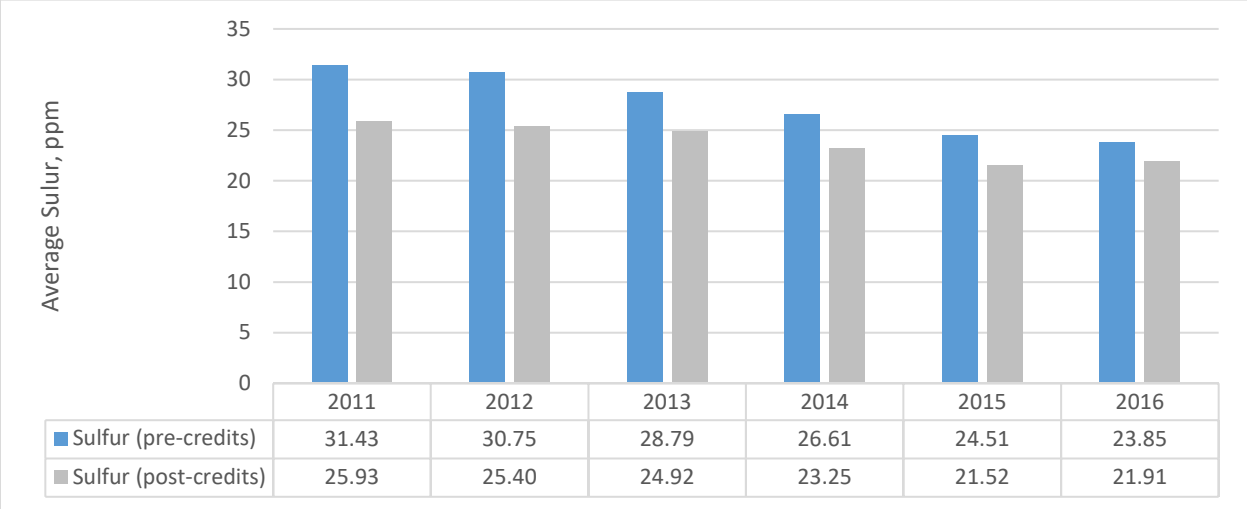


	2011	2012	2013	2014	2015	2016
Volume above 30 ppm	61.1	57.1	47.3	47.8	37.5	23.5
Volume at or below 30 ppm	53.5	57.8	67.6	68.3	82.0	98.6

Figure 4 shows the average sulfur before and after use of gasoline sulfur credits from 2011 through 2016. The blue bars (pre-credits) include all facilities averaging 30 ppm or less (credit generators), and all facilities averaging over 30 ppm (credit users). The gray bars (post-credits) include all facilities under 30 ppm (credit generators), and all facilities equal to 30 ppm (credit users, post-credits). The difference between the blue and gray bars decreased from approximately 5.5 ppm in 2011 to approximately 2.0 ppm in 2016, indicating a decrease in the number of credits used for compliance with the 30 ppm average sulfur standard.[25]

[25] The differences in sulfur before and after using credits also include the effect of refiners and importers using credits that they had generated and banked prior to 2011.

Figure 4: Average Annual Sulfur Content Before and After Using Credits



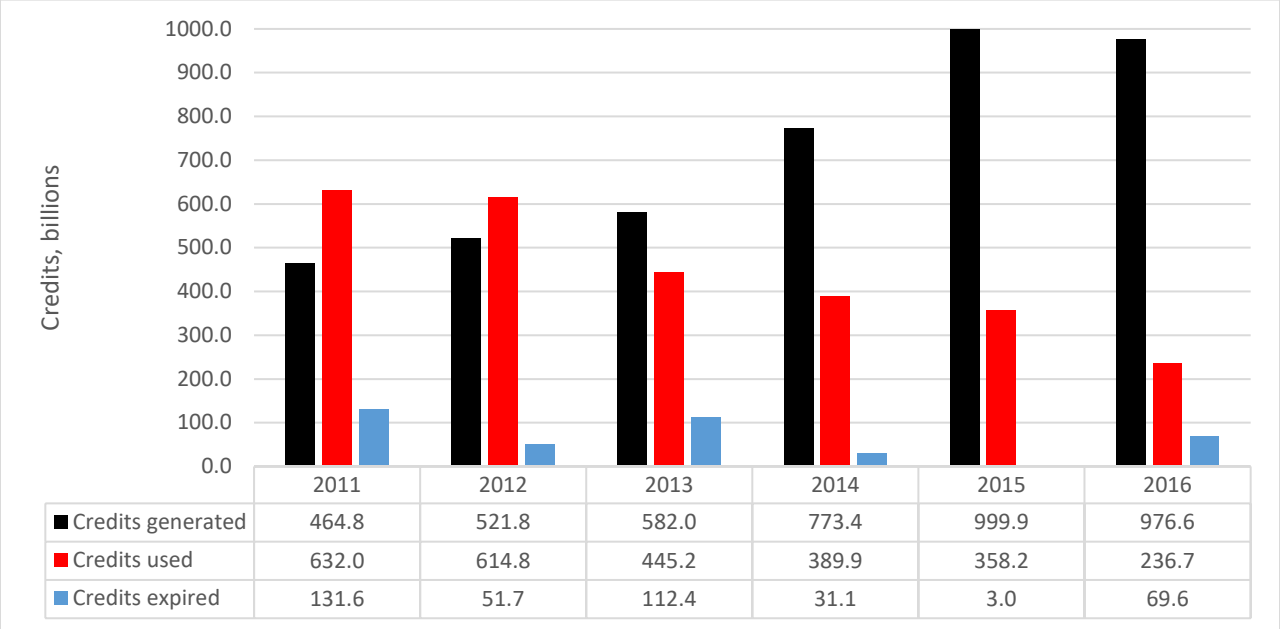
	2011	2012	2013	2014	2015	2016
Sulfur (pre-credits)	31.43	30.75	28.79	26.61	24.51	23.85
Sulfur (post-credits)	25.93	25.40	24.92	23.25	21.52	21.91

2. Credit Generation and Use

Figure 5 shows total annual credit generation, use, and expiration from 2011 through 2016. Credit generation increased by approximately 512 billion credits from 2011 through 2016, and credit use decreased by approximately 395 billion credits from 2011 through 2016, as more facilities produced gasoline containing 30 ppm sulfur or less. The increases in credit generation in 2014, 2015, and 2016 are likely due to refiners and importers choosing to generate "early" Tier 3 credits for use in 2017 through 2019, following publication of the final Tier 3 rule on April 28, 2014. The number of expired credits decreased from 131.6 billion in 2011 to 3.0 billion in 2015, indicating improving overall efficiency in management of credit inventories by refiners and importers.[26] Expired credits increased to 69.6 billion in 2016, as more refiners and importers further reduced gasoline sulfur in preparation for Tier 3 compliance, and thus needed to use fewer credits for compliance with Tier 2's 30 ppm average sulfur standard. All credits that expired in 2016 were generated in 2011, and expired at the end of their five-year life.

[26] Credits may be used up to five years following the year in which they were generated, and expire if unused after five years. There are some cases where refiners and importers have let credits expire, resulting in over-compliance with the 30 ppm average sulfur standard.

Figure 5: Credit Generation, Use and Expiration



	2011	2012	2013	2014	2015	2016
Credits generated	464.8	521.8	582.0	773.4	999.9	976.6
Credits used	632.0	614.8	445.2	389.9	358.2	236.7
Credits expired	131.6	51.7	112.4	31.1	3.0	69.6

Figure 6 and Table 4 show credit use by year of credit generation. Figure 6 and Table 4 indicate how refiners and importers manage their credit inventories.[27] They show that refiners and importers typically try to use credits as late as possible by banking them until the last year in which they can be used, and using them in that last year. For example, most credits used in 2016 were generated in 2011, and most credits used in 2015 were generated in 2010. Almost all credits used in 2011 were generated prior to 2011.

[27] The EPA periodically posts updated data on current inventories of gasoline sulfur credits at https://www.epa.gov/fuels-registration-reporting-and-compliance-help/fuels-averaging-banking-and-trading-abt-credit-data. As of February 7, 2018, refiners and importers held a total of 3,717 billion gasoline sulfur credits.

Figure 6: Credit Use (colors show year of credit generation)

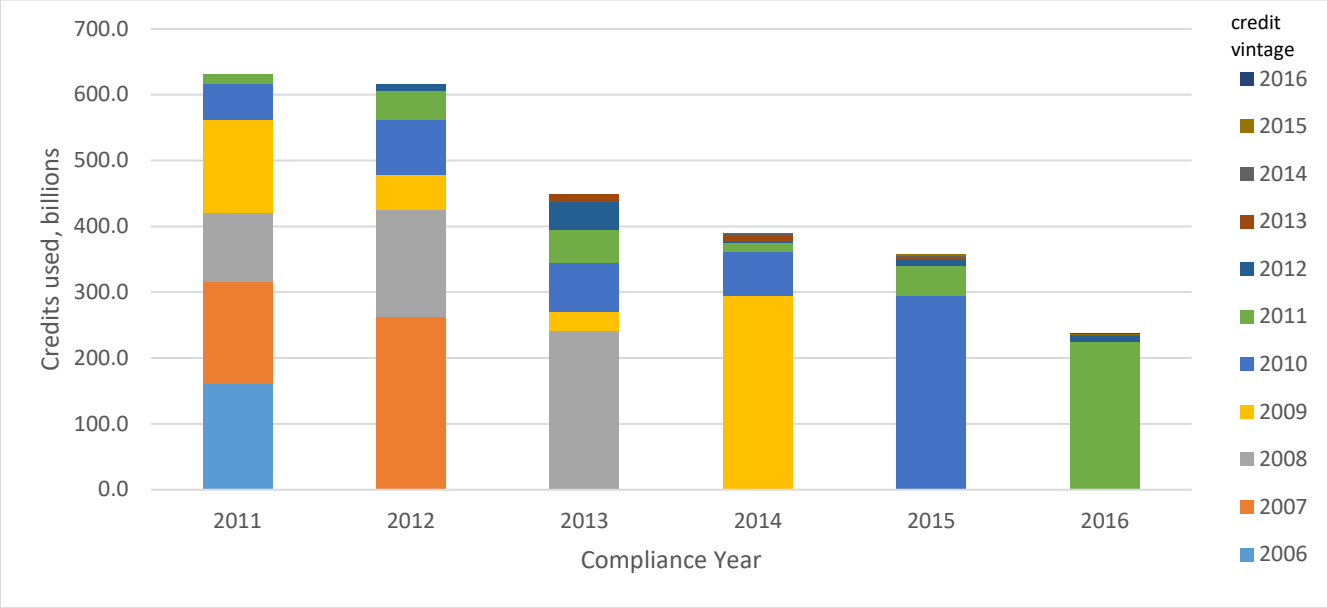


Table 4: Credit Use (in billions), by Year of Credit Generation

Year of Credit Use

Year of Credit Generation	2011	2012	2013	2014	2015	2016
2006	160.8	0.0	0.0	0.0	0.0	0.0
2007	155.6	260.1	0.0	0.0	0.0	0.0
2008	104.2	163.9	241.1	0.0	0.0	0.0
2009	141.5	52.1	29.5	293.9	0.0	0.0
2010	55.0	84.8	73.3	66.8	294.3	0.0
2011	14.9	43.4	50.4	13.4	46.0	224.1
2012	0.0	10.5	40.4	3.1	8.2	9.9
2013	0.0	0.0	10.6	10.5	4.4	1.0
2014	0.0	0.0	0.0	2.2	2.6	0.6
2015	0.0	0.0	0.0	0.0	2.6	0.9
2016	0.0	0.0	0.0	0.0	0.0	0.3
Total	632.0	614.8	445.2	389.9	358.2	236.7

Credits can be traded only twice before they are used, to enable reasonable enforcement oversight of the program. Figure 7 and Table 5 present credit use data according to the number of times credits were transferred between refiners and/or importers. CC0 credits are credits that were never transferred by the refiner or importer that generated them, CC1 credits are credits that were transferred once, and CC2 credits are credits that were transferred twice. Figure 7 and

Table 5 indicate that a significant percentage of credits used by refiners and importers each year for compliance are obtained from other refiners and/or importers. [28]

Figure 7: Credit Use (colors show numbers of times credits were transferred)

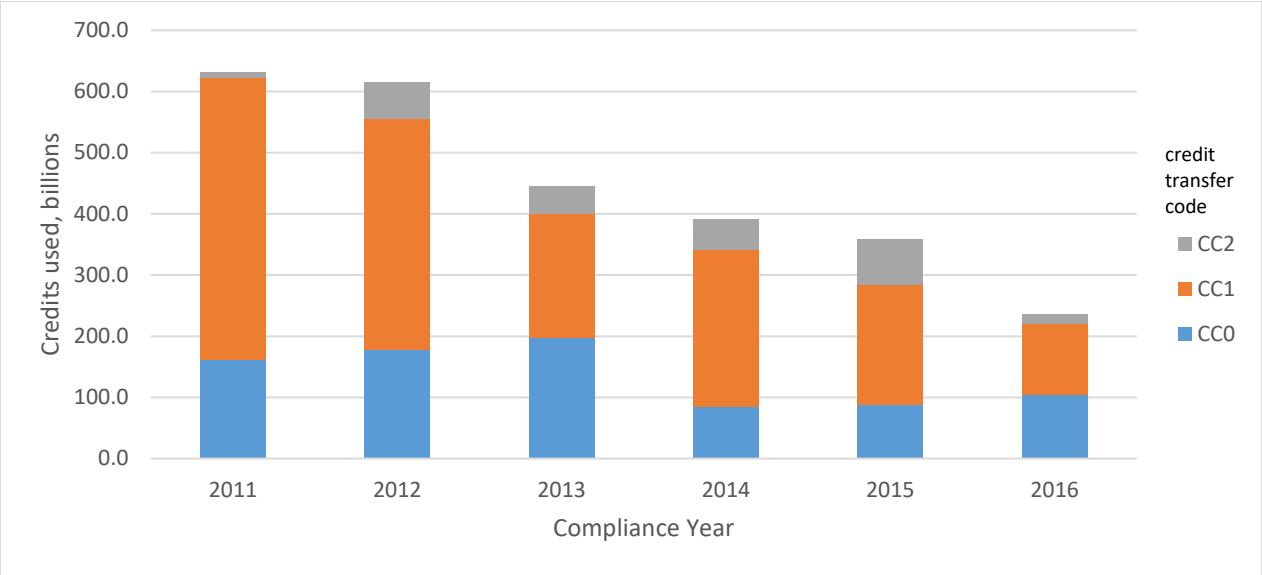


Table 5: Credit Use (in billions), by Number of Times Credits Transferred

Year of Credit Use	Type of Credit Used			Total Use
	CC0	CC1	CC2	
2011	161.8	460.8	9.5	632.0
2012	177.4	378.2	59.2	614.8
2013	197.8	201.8	45.5	445.2
2014	85.2	255.6	49.2	389.9
2015	88.1	196.4	73.7	358.2
2016	104.2	116.6	16.0	236.7

3. Combined Annual Data from GSF030X and GSF0100 Reports

Tables 6 through 11 show the combined data from the GSF030X reports and the GSF0100 reports for each year from 2011 through 2016, summarizing the data for credit generators, credit users, and total combined credit generators and users. Each table quantifies the relationship between the number of reporting facilities, gasoline volume/sulfur, and quantity of credits generated/used for each year.

[28] The limit on credit transfers only applied to transfers between companies (intercompany transfers). Companies that owned more than one refinery and/or more than one import facility could transfer credits between their refineries and import facilities (intracompany transfers) without limit. The EPA is aware of a few instances where refiners accidentally assigned a credit transfer code of CC1 (instead of CC0) to intracompany credit transfers, so the number of intercompany-transferred credits is expected to be slightly less than indicated in Figure 7 and Table 5.

For credit generators, each table shows the number of facilities that generated credits (or had an average sulfur of 30 ppm), total gasoline production, average sulfur, and total credits generated. For credit users, each table shows the number of facilities that used credits, total gasoline production, average sulfur before use of credits, total credits used, and average sulfur after credit use. For some years, average sulfur after credit use is slightly lower than 30 ppm due to over-compliance by some facilities which used more credits than necessary to meet the 30 ppm average sulfur standard.

Table 6: 2011 Combined Data from GSF0301 and GSF0100 Reports

Report	GSF0301	GSF0301	GSF0301	GSF0100	GSF0100	GSF0301
	Number of facilities	Gasoline produced, gallons	Average sulfur, ppm	Total credits generated, ppm-gallons	Total credits used, ppm-gallons	Average sulfur after credit use, ppm
Sulfur credit generators	257	53,474,891,296	21.27	464,872,004,037	----------	21.27
Sulfur credit users	85	61,143,086,933	40.32	----------	631,997,949,988	29.99
Total	342	114,617,978,229	31.43	464,872,004,037	631,997,949,988	25.93

Table 7: 2012 Combined Data from GSF0301 and GSF0100 Reports

Report	GSF0301	GSF0301	GSF0301	GSF0100	GSF0100	GSF0301
	Number of facilities	Gasoline produced, gallons	Average sulfur, ppm	Total credits generated, ppm-gallons	Total credits used, pm-gallons	Average sulfur after credit use, ppm
Sulfur credit generators	297	57,840,914,920	20.85	521,752,433,180	----------	20.85
Sulfur credit users	95	57,139,164,526	40.76	----------	614,752,724,705	30.00
Total	392	114,980,079,446	30.75	521,752,433,180	614,752,724,705	25.40

Table 8: 2013 Combined Data from GSF0301 and GSF0100 Reports

Report	GSF0301	GSF0301	GSF0301	GSF0100	GSF0100	GSF0301
	Number of facilities	Gasoline produced, gallons	Average sulfur, ppm	Total credits generated, ppm-gallons	Total credits used, ppm-gallons	Average sulfur after credit use, ppm
Sulfur credit generators	331	67,617,998,125	21.36	581,985,499,587	----------	21.36
Sulfur credit users	90	47,297,601,663	39.41	----------	445,166,177,796	29.99
Total	421	114,915,599,788	28.79	581,985,499,587	445,166,177,796	24.92

Table 9**:** 2014 Combined Data from GSF0301 and GSF0100 Reports

Report	GSF0301	GSF0301	GSF0301	GSF0100	GSF0100	GSF0301
	Number of facilities	Gasoline produced, gallons	Average sulfur, ppm	Total credits generated, ppm-gallons	Total credits used, ppm-gallons	Average sulfur after credit use, ppm
Sulfur credit generators	327	68,296,832,085	18.54	773,369,798,536	----------	18.53
Sulfur credit users	84	47,841,073,575	38.13	----------	389,948,545,636	29.99
Total	411	116,137,905,660	26.61	773,369,798,536	389,948,545,636	23.25

Table 10**:** 2015 Combined Data from GSF0301 and GSF0100 Reports

Report	GSF0301	GSF0301	GSF0301	GSF0100	GSF0100	GSF0301
	Number of facilities	Gasoline produced, gallons	Average sulfur, ppm	Total credits generated, ppm-gallons	Total credits used, ppm-gallons	Average sulfur after credit use, ppm
Sulfur credit generators	337	81,954,525,179	17.66	999,863,511,293	----------	17.66
Sulfur credit users	71	37,524,437,331	39.48	----------	358,167,066,402	29.95
Total	408	119,478,962,510	24.51	999,863,511,293	358,167,066,402	21.52

Table 11: 2016 Combined Data from GSF0301 and GSF0100 Reports

Report	GSF0301	GSF0301	GSF0301	GSF0100	GSF0100	GSF0301
	Number of facilities	Gasoline produced, gallons	Average sulfur, ppm	Total credits generated, ppm-gallons	Total credits used, ppm-gallons	Average sulfur after credit use, ppm
Sulfur credit generators	371	98,634,876,413	19.99	976,572,320,993	----------	19.99
Sulfur credit users	51	23,546,921,946	39.99	----------	236,741,413,865	29.97
Total	422	122,181,798,359	23.85	976,572,320,993	236,741,413,865	21.91

4. Compliance with 80 ppm Per-Gallon Standard

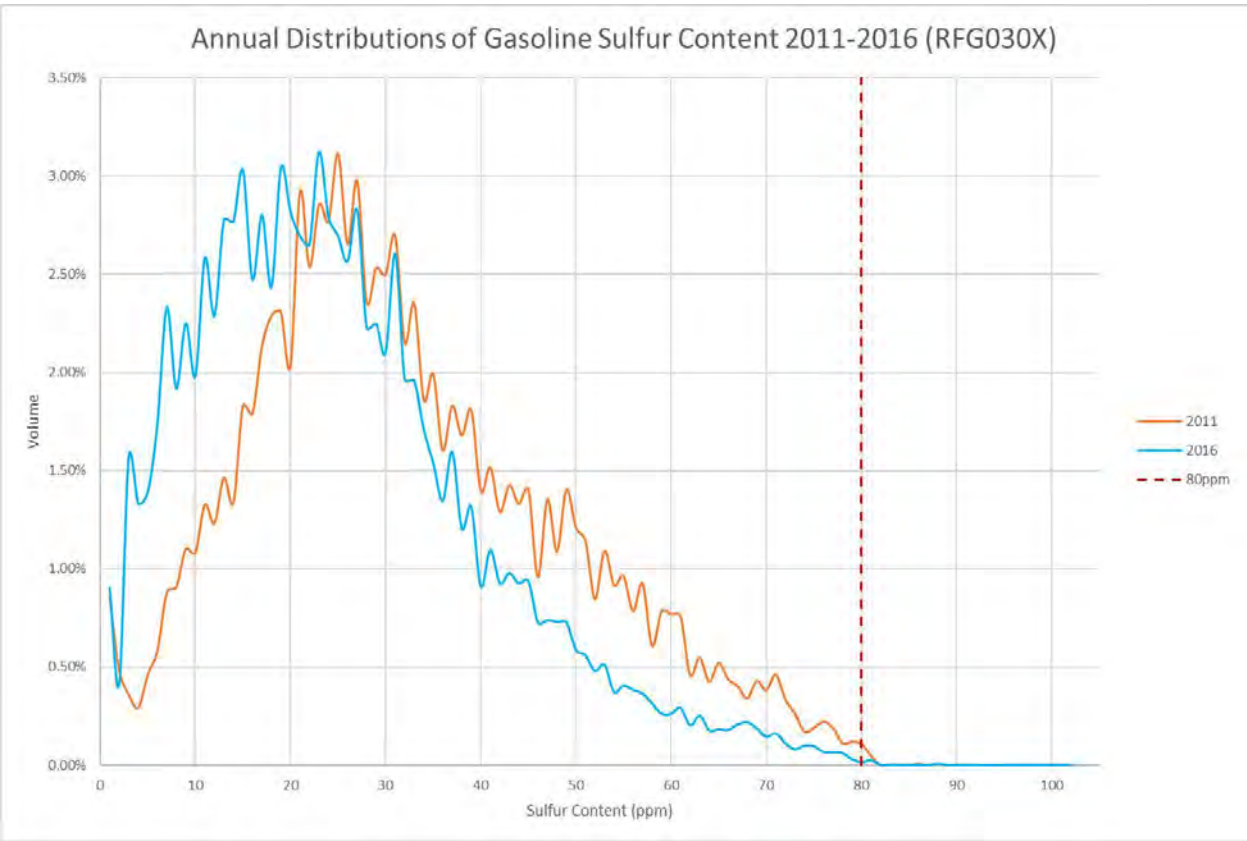
Figure 8 illustrates how sulfur in individual batches of gasoline has changed from 2011 to 2016. Based on batch data submitted in the RFG030X reports, Figure 8 shows the percentage of total gasoline for 2011 (orange line) and 2016 (blue line), as a function of sulfur content (in 1 ppm increments). As expected, the 2016 distribution curve is shifted to the left compared to the 2011 curve, due to sulfur reductions by refiners and importers from 2011 to 2016.

Figure 8 also illustrates compliance by refiners and importers with the 80 ppm per-gallon sulfur standard. The right side of the curve indicates that a small percentage (0.014 percent) of total gasoline exceeded the 80 ppm per-gallon standard in 2011, and an even smaller percentage (0.004 percent) exceeded 80 ppm in 2016. From 2011 through 2016, a total of only 81 batches out of over 300,000 batches were reported containing more than 80 ppm sulfur. Thirty-four of these batches were reported with a sulfur concentration of 970 ppm, which is the default sulfur concentration specified in 40 CFR 80.80 that is used when a refiner or importer doesn't have a

sulfur test result for a batch of gasoline. Another 34 of these batches contained less than 95 ppm sulfur, which is the per-gallon sulfur standard downstream of refineries and import facilities. The remaining 13 batches contained between 95 and 175 ppm sulfur.

The total volume of these 81 batches was 27 million gallons, which represented approximately 0.004 percent of the total reported volume of 703 billion gallons from 2011 through 2016. Because the volume of these 81 batches was so small relative to the total volume of gasoline consumed, and individual batches of gasoline are combined and blended in pipelines, terminals and retail stations, gasoline use in vehicles is likely to still have been below the 95 ppm downstream per-gallon standard.

Figure 8: Annual Distribution of Gasoline Sulfur Content in 2011 and 2016 (from RFG030X Reports)



IV. Conclusion

The gasoline sulfur analysis presented in this report shows a high level of compliance with refinery and importer annual average and per-gallon sulfur standards under the Tier 2 gasoline sulfur program from 2011 through 2016, and a gradual decline of average sulfur levels in anticipation of compliance with the 10 ppm annual average standard beginning in 2017. The gasoline sulfur credit program analysis further illustrates the beneficial flexibility it has provided the industry in lowering gasoline sulfur levels over time.

Compliance data reported to the EPA by refiners confirms several key findings:

- Refiners and importers have taken full advantage of the flexibilities of the ABT program to reduce sulfur levels at a rate and time that is most conducive to their business plans.
- The national average reported sulfur content of gasoline, before credits, decreased 24 percent from 31.43 ppm in 2011 to 23.85 ppm in 2016. This downward trend should continue as the Tier 3 sulfur standards phase in beginning in 2017.
- The percentage of gasoline produced or imported at facilities averaging 30 ppm sulfur or less on an annual basis increased from 46.7 percent in 2011 to 80.7 percent in 2016.
- Refiners optimized sulfur credit use to avoid the expiration of unused credits in 2015 and have needed progressively fewer credits to achieve compliance with the 30 ppm annual average sulfur standard from 2011 through 2016.
- Refiners appear to have generated a large number of "early" Tier 3 sulfur credits between 2013 and 2016 in anticipation of complying with the 10 ppm annual average sulfur standard beginning in 2017.

This report, along with other fuels trends analyses and sulfur compliance credit data posted on the agency's website, provide comprehensive information about the EPA's national gasoline sulfur control programs and their effects in reducing gasoline sulfur levels in the U.S.[29] The EPA will continue to make gasoline sulfur data available to maximize the transparent implementation of its regulatory programs.

[29] See https://www.epa.gov/fuels-registration-reporting-and-compliance-help/public-data-gasoline-programs.

V. Appendix

Life of a Sulfur ABT Credit