

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2013: Revision to Refinery Emissions Estimate

Revision Implemented in Public Review Draft

Overview of Method in 2014 Inventory (estimates for 1990-2012)

Inventory estimates of refinery emissions included in the petroleum systems source category have been based on emission factors that were derived from studies conducted by EPA and the American Petroleum Institute (API) between 1992 and 1996. The emission factors were multiplied by activity data obtained each year from the U.S. Energy Information Agency's *Gross Inputs to Refineries*, and Oil and Gas Journal's *World-wide Refining Report*.

The previous Inventory method for the petroleum systems source category included methane (CH₄) emissions released to the atmosphere as fugitive emissions, vented emissions, emissions from operational upsets, and emissions from fuel combustion by certain equipment at refineries. Fugitive and vented carbon dioxide (CO₂) emissions from petroleum refineries were also included. Combustion CO₂ emissions from fuel use (e.g., in process heaters) are accounted for in the fossil fuels combustion source category, and not taken into account in the petroleum systems source category.

Overview of Revision Implemented in Public Review Draft

Petroleum refineries have been reporting to the Petroleum Refineries source category (subpart Y) of the Greenhouse Gas Reporting Program (GHGRP) since 2010, and now four years of data from 2010 to 2013 are available. For the public review draft of EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013* released in 2015 (2015 Inventory), EPA has revised the refineries portion of the petroleum systems source category calculations to use the data available from GHGRP subpart Y.

Revised Approach for 2015 Inventory

Stakeholder comments to the 2014 Inventory supported use of the GHGRP data on petroleum refineries to update the GHG Inventory estimates. Stakeholders noted significant differences between GHGRP results and the GHG Inventory estimates for this source. Taking into account this feedback, EPA noted in the "Planned Improvements" section of the 2014 Inventory that analysis of GHGRP data for petroleum refineries is a priority for the 2015 Inventory. EPA then solicited feedback from expert reviewers¹ on a proposed revised methodology for the 2015 Inventory that is based on GHGRP data. Expert reviewers generally supported the revised methodology.

Petroleum refineries report under subpart Y of the GHGRP. All petroleum refineries, regardless of size, are required to report to GHGRP (i.e., there is no threshold for this source).² Emissions from petroleum refineries are estimated using methods prescribed in the GHGRP including direct measurement and engineering calculations.

¹ Every year, the Inventory undergoes an expert review period during which a first draft of the document is sent to a select list of technical experts outside of EPA. The purpose of the Expert Review is to encourage feedback on the methodological and data sources used in the current Inventory, especially for sources which have experienced any changes since the previous Inventory. This memorandum references feedback from 2015 Inventory expert reviewers.

² While this source category has no threshold and therefore all facilities in this source category were required to report emissions to the GHGRP from 2010-2012, due to GHGRP provisions that allow facilities to discontinue reporting under specified circumstances, it is possible that not all refineries will continue to report after 2012. The GHGRP allows for a facility to discontinue reporting if a facility's annual reports submitted under the rule show that emissions were less than 25,000 metric tons of CO₂ equivalent per year for 5 consecutive years, or less than 15,000 metric tons of CO₂ equivalent per year for 3 consecutive years.

Tables 1 and 2 below compare 2012 process-level refinery emissions calculated in the 2014 Inventory to the corresponding 2012 GHGRP emissions (reflecting the most recent submissions from facilities as of August 18, 2014) for CH₄ and CO₂, respectively.

Table 1. 2012 Refinery CH₄ Emissions from GHG Inventory and GHGRP Subpart Y

GHG Inventory Source	2012 Inventory Emissions (MT CH ₄)	GHGRP Emission Source	2012 GHGRP Emissions (MT CH ₄)
Vented and Fugitive Emissions			
Fixed Roof Tanks	278	All storage Tanks	1,592
Floating Roof Tanks	9		
System Blowdowns	14,378	Uncontrolled Blowdowns	5,136
Asphalt Blowing	624	Asphalt Blowing	292
Fuel Gas System	1,210	Equipment Leaks ^a	2,704
		Process Vents	5,505
		CEM Vents	48
		Loading Operations	19
Wastewater Treating ^a	198		
Cooling Towers ^a	248		
Sub-Total	16,945		15,743
Combustion Emissions			
Atmospheric Distillation	387		
Vacuum Distillation	180		
Thermal Operations	96	Catalytic Cracking/Reforming/Fluid Coking	1,473
Catalytic Cracking	182		
Catalytic Reforming	157		
Catalytic Hydrocracking	78		
Hydrorefining	34		
Hydrotreating	472		
Alkylation/Polymerization	96		
Aromatics/Isomeration	13		
Lube Oil Processing	0		
Engines	118		
Flares	20	Flares	13,229
		Delayed Coking	1,201
		Coke Calcining	24
Sub-Total	1,834		15,928
Total	18,780		31,671

a – “Equipment leaks” fugitive emissions in Subpart Y include emissions from valves, pumps, compressors, pressure relief valves, connectors, flanges, and open-ended lines—and are most analogous to the “fuel gas system” source in the current Inventory.³ The current Inventory fugitive emission factors for wastewater treating and cooling towers include other non-component-based losses (e.g., evaporative).⁴ EPA’s proposal is to use the existing methodology to fully account for emissions from these sources, as shown in Table 3 below.

³ Subpart Y cites *Protocol for Equipment Leak Emissions Estimates* (EPA-453/R-95-017, NTIS PB96-175401); see section 2.2.2 of the document.

⁴ The basis for the current Inventory methodology regarding cooling towers and wastewater treatment (*Methane Emissions from the U.S. Petroleum Industry* EPA-600/R-99-010, Table 5-11) cites AP-42 Chapter 5.1 for the cooling tower emission factor and *Model for Evaluation of Refinery and Synfuels VOC Emission Data* Vol. I, EPA-600/7-85-022a for the wastewater treatment emission factor. Per AP-42 Section 5.1.3.5: “Atmospheric emissions from the cooling tower consist of fugitive VOCs and gases stripped from the cooling

As shown in Table 1, several CH₄ emission sources are grouped differently between the two data sets. The 2014 Inventory estimates vented emissions from fixed roof tanks separately from fugitive emissions from floating roof tanks, and estimates combustion CH₄ emissions from process heaters and boilers by individual process unit. The 2014 Inventory also estimates wastewater and cooling tower CH₄ emissions, which are not reporting elements under GHGRP subpart Y. The combustion emissions reported under GHGRP subpart Y are limited to combustion reactions that occur within specific process equipment. The fuel combustion emissions from conventional stationary combustion units at refineries including heaters, boilers, engines and turbines are not reported under subpart Y, but are reported under subpart C (and are not included in Table 1).

Note, combined vented and fugitive CH₄ emissions in Table 1 are similar between the two data sets; and combustion CH₄ emissions from flares in particular result in higher combustion emissions in the GHGRP Subpart Y data set compared to the current GHG Inventory.

As shown in Table 2, the 2014 Inventory methodology for petroleum systems accounted for asphalt blowing as the only source of CO₂ emissions from refineries. Table 2 matches the current GHG Inventory sources and therefore presents only the asphalt blowing CO₂ emissions source.

Table 2. 2012 Refinery Carbon Dioxide Emissions from GHG Inventory and GHGRP

National Emission Inventory Source	2012 Inventory Emissions (MT CO ₂)	Subpart Y Emission Source	2012 Subpart Y Emissions (MT CO ₂)
Asphalt Blowing	13,937	Asphalt Blowing	116,850

In addition to asphalt blowing, the GHGRP subpart Y accounts for six other sources of CO₂ from refineries: CEM data (i.e., process-specific stack measurements), coke calcining, catalytic regeneration, process vents, sulfur recovery, and flaring. EPA sought comment from 2015 Inventory expert reviewers on implementing an approach consistent with IPCC guidelines across the 2015 Inventory—adding flaring CO₂ emissions and non-combustion CO₂ emissions (i.e., process vents) to the GHG Inventory; expert reviewers generally supported implementing such a revision. In the public review draft estimates, the CO₂ emission factors for flaring and process vents shown in Table 4 below have been applied for all years of the time series.

As with CH₄, the GHGRP accounts for CO₂ emissions from conventional stationary fuel combustion units (heaters, boilers, engines, and turbines) under subpart C. Including CO₂ emissions from fuel combustion reported under GHGRP subpart C in the refineries portion of the petroleum systems source category of the Inventory would result in double-counting with the fossil fuels combustion source category.

EPA proposed to expert reviewers that the 2010 through 2013 GHGRP subpart Y emissions for the sources identified on the right side of Tables 1 and 2 be considered to replace current petroleum systems source-level estimates for the public review draft of the 2015 Inventory. Expert reviewers generally agreed with this approach. For the two sources currently included in the Inventory but not reported by the GHGRP, cooling towers and wastewater treating, the current Inventory method will be used to estimate emissions from these sources. Expert reviewers generally agreed with this approach, but raised concern as to whether counting emissions from these two sources over the entire time series is an accurate approach; request for stakeholder feedback on this issue is included at the end of this memorandum.

water as the air and water come into contact.” Per *Model for Evaluation of Refinery and Synfuels VOC Emission Data*: “Primary sources of VOC emissions from wastewater treatment systems are evaporative emissions...”

Revised Approach for Calculating 1990-2009 Estimates

Since GHGRP data only cover recent years of the Inventory time series, EPA developed an extrapolation approach to develop consistent emissions estimates back to 1990. EPA used throughput-based emission factors developed from recent GHGRP data in conjunction with publicly available throughput data from Department of Energy/Energy Information Administration (e.g., refinery feed data) to effectively scale GHGRP emissions to reflect activity in earlier years. Expert reviewers commented that in addition to considering refinery throughput dynamics over time, changes in refinery complexity over time ideally would be taken into account when scaling emissions for earlier years; however, a methodology to do so was not proposed.

Table 3. Comparison of Previous and Revised Refinery CH₄ Emission Factors

Previous Inventory CH ₄ Emission Factor		Draft Inventory Emission Factor (scf CH ₄ /mbbl refinery feed)	
Fixed Roof Tanks	20.6 scf/mbbl heavy crude input	All storage Tanks	10.71
Floating Roof Tanks	587 scf/tank		
System Blowdowns	137 scf/mbbl total crude input	Uncontrolled Blowdowns	51.03
Asphalt Blowing	2555 scf/mbbl asphalt production	Asphalt Blowing	2.78
Fuel Gas System	439,000 scf/refinery	Equipment Leaks	26.05
		Process Vents	43.14
		CEM Vents	0.33
		Loading Operations	0.24
Wastewater Treating	1.88 scf/mbbl total crude input	Wastewater Treating	1.88
Cooling Towers	2.39 scf/mbbl total crude input	Cooling Towers	2.39
Atmospheric Distillation	3.61 scf/mbbl total crude input		
Vacuum Distillation	3.61 scf/mbbl unit throughput		
Thermal Operations	6.01 scf/mbbl unit throughput	Catalytic Cracking/ Reforming/ Fluid Coking	13.97
Catalytic Cracking	5.17 scf/mbbl unit throughput		
Catalytic Reforming	7.22 scf/mbbl unit throughput		
Catalytic Hydrocracking	7.22 scf/mbbl unit throughput		
Hydrorefining	2.17 scf/mbbl unit throughput		
Hydrotreating	6.50 scf/mbbl unit throughput		
Alkylation/Polymerization	12.6 scf/mbbl unit throughput		
Aromatics/Isomeration	1.80 scf/mbbl unit throughput		
Lube Oil Processing	0.0 scf/mbbl unit throughput		
Engines	0.006 scf/hp-hr		
Flares	0.189 scf/mbbl total crude input	Flares	123.98
		Delayed Coking	16.63
		Coke Calcining	0.27

Table 4. Comparison of Previous and Revised Refinery CO₂ Emission Factors

Previous Inventory CO ₂ Emission Factor		Draft Inventory Emission Factor (scf CO ₂ /mbbl refinery feed)	
Asphalt Blowing	20,736 scf CO ₂ /mbbl asphalt production	Asphalt Blowing	367
-	-	Process Vents	19
-	-	Flaring	839

Results

The impact of revising the refinery emission factors to use those listed on the right side of Tables 3 and 4 is presented in Table 5 below. The emissions of CH₄ and CO₂ are compared separately. The impact of the new CH₄ factors is an increase of CH₄ emissions for years across the time series that ranges from 40 to 80 percent. The impact of the new CO₂ factors is an increase in CO₂ emissions for years across the time series by two orders of magnitude.

Table 5. Impact of Revised Emission Factors

	1990	1995	2000	2005	2010	2013
Previous Emissions (MT CH ₄)	17,622	18,055	19,277	19,342	18,586	18,862
Revised Emissions (MT CH ₄)	27,493	28,650	30,976	31,206	26,807	33,964
Previous Emissions (MT CO ₂)	17,781	18,686	21,080	20,478	15,265	13,998
Revised Emissions (MT CO ₂)	4,070,108	4,241,363	4,585,706	4,619,709	3,835,619	5,540,353

Request for Stakeholder Feedback

EPA seeks feedback on this approach to revising petroleum refinery emissions:

- The use of GHGRP subpart Y data for revising refinery emissions in the petroleum systems Inventory.
- The addition of cooling towers and wastewater treating emissions from the previous Inventory to the emissions estimates based on data from GHGRP subpart Y, including time series considerations (e.g., whether it is accurate to count emissions from each of these sources for early as well as recent years, since mitigation of emissions from these sources may have evolved over time across the industry).
- The approach for calculating emissions from 1990-2009, including the use of updated factors across the full time series.
- The revised approach above reflects subpart Y data for sources that were not previously included in the petroleum systems segment refinery emissions estimate of the GHG Inventory. EPA seeks comment on the inclusion of additional sources in the petroleum refineries estimates. Such sources include vented CH₄ emissions from the Subpart Y categories of Process Vents, CEM Vents, and Loading Operations; and CO₂ emissions from the Subpart Y categories of Flaring and Process Vents. Calculated emission factors are presented in Tables 3 and 4 above for these sources.
- Subpart Y also collects data on combustion sources that are covered in the GHG Inventory estimates for Fossil Fuel Combustion. Those categories include catalytic cracking, reforming, fluid coking, delayed coking, coke calcining, CEM data, coke calcining, catalyst regeneration and sulfur recovery. Some sources that have been historically included in the Inventory estimate for CH₄ from petroleum refineries are combustion-related emissions (those listed in the bottom half of Table 1). EPA is cross-checking the Inventory treatment of these sources against IPCC guidance and other sections of the Inventory to assess whether there is double-counting.