

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

### **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 (CH<sub>4</sub>) 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 (CO<sub>2</sub>) emissions from petroleum refineries were also included. Combustion CO<sub>2</sub> 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 2015 Inventory**

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. In the 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 reviewers<sup>1</sup> and public reviewers on a proposed revised methodology for the 2015 Inventory that is based on GHGRP data. 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).<sup>2</sup> Emissions from petroleum refineries are estimated using methods prescribed in the GHGRP including direct measurement and engineering calculations.

Tables 1 and 2 below compare 2012 process-level refinery emissions calculated in the 2014 Inventory to the corresponding 2012 GHGRP emissions (reflecting submissions from facilities as of August 18, 2014) for CH<sub>4</sub> and CO<sub>2</sub>, respectively.

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<sup>1</sup> 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.

<sup>2</sup> 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 CO<sub>2</sub> equivalent per year for 5 consecutive years, or less than 15,000 metric tons of CO<sub>2</sub> equivalent per year for 3 consecutive years.

**Table 1. 2012 Refinery CH<sub>4</sub> Emissions from GHG Inventory and GHGRP Subpart Y**

GHG Inventory Source	2012 Inventory Emissions (MT CH <sub>4</sub> )	GHGRP Emission Source	2012 GHGRP Emissions (MT CH <sub>4</sub> )
<b>Vented and Fugitive Emissions</b>			
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 <sup>a</sup>	2,704
		Process Vents	5,505
		CEM Vents	48
		Loading Operations	19
Wastewater Treating <sup>a</sup>	198		
Cooling Towers <sup>a</sup>	248		
<b>Sub-Total</b>	<b>16,945</b>		<b>15,743</b>
<b>Combustion Emissions</b>			
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
<b>Sub-Total</b>	<b>1,834</b>		<b>15,928</b>
<b>Total</b>	<b>18,780</b>		<b>31,671</b>

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.<sup>3</sup> The current Inventory fugitive emission factors for wastewater treating and cooling towers include other non-component-based losses (e.g., evaporative).<sup>4</sup> EPA’s used the existing methodology to fully account for emissions from these sources, as shown in Table 3 below.

As shown in Table 1, several CH<sub>4</sub> 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,

<sup>3</sup> 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.

<sup>4</sup> 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 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...”

and estimates combustion CH<sub>4</sub> emissions from process heaters and boilers by individual process unit. The 2014 Inventory also estimates wastewater and cooling tower CH<sub>4</sub> 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 CH<sub>4</sub> emissions in Table 1 are similar between the two data sets; and combustion CH<sub>4</sub> 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 CO<sub>2</sub> emissions from refineries. Table 2 matches the current GHG Inventory sources and therefore presents only the asphalt blowing CO<sub>2</sub> emissions source.

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

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

In addition to asphalt blowing, the GHGRP subpart Y accounts for six other sources of CO<sub>2</sub> 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 and public reviewers on implementing an approach consistent with IPCC guidelines across the 2015 Inventory—adding flaring CO<sub>2</sub> emissions and non-combustion CO<sub>2</sub> emissions (i.e., process vents) to the GHG Inventory; reviewers generally supported implementing such a revision. In the 2015 Inventory, the CO<sub>2</sub> emission factors for flaring and process vents shown in Table 4 below have been applied for all years of the time series.

As with CH<sub>4</sub>, the GHGRP accounts for CO<sub>2</sub> emissions from conventional stationary fuel combustion units (heaters, boilers, engines, and turbines) under subpart C. Including CO<sub>2</sub> 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 in the Inventory.

EPA used the 2010 through 2013 GHGRP subpart Y emissions for the sources identified on the right side of Tables 1 and 2 to replace current petroleum systems source-level estimates for the 2015 Inventory. Inventory 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 previous Inventory method was used to estimate emissions from these sources. Inventory 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.

**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. 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 CH<sub>4</sub> Emission Factors**

Previous Inventory CH <sub>4</sub> Emission Factor		Draft Inventory Emission Factor (scf CH <sub>4</sub> /mbl refinery feed)	
Fixed Roof Tanks	20.6 scf/mbl heavy crude input	All storage Tanks	10.71
Floating Roof Tanks	587 scf/tank		
System Blowdowns	137 scf/mbl total crude input	Uncontrolled Blowdowns	51.03
Asphalt Blowing	2555 scf/mbl 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/mbl total crude input	Wastewater Treating	1.88
Cooling Towers	2.39 scf/mbl total crude input	Cooling Towers	2.39
Atmospheric Distillation	3.61 scf/mbl total crude input		
Vacuum Distillation	3.61 scf/mbl unit throughput		
Thermal Operations	6.01 scf/mbl unit throughput	Catalytic Cracking/ Reforming/ Fluid Coking	13.97
Catalytic Cracking	5.17 scf/mbl unit throughput		
Catalytic Reforming	7.22 scf/mbl unit throughput		
Catalytic Hydrocracking	7.22 scf/mbl unit throughput		
Hydrorefining	2.17 scf/mbl unit throughput		
Hydrotreating	6.50 scf/mbl unit throughput		
Alkylation/Polymerization	12.6 scf/mbl unit throughput		
Aromatics/Isomeration	1.80 scf/mbl unit throughput		
Lube Oil Processing	0.0 scf/mbl unit throughput		
Engines	0.006 scf/hp-hr		
Flares	0.189 scf/mbl total crude input	Flares	123.98
		Delayed Coking	16.63
		Coke Calcining	0.27

**Table 4. Comparison of Previous and Revised Refinery CO<sub>2</sub> Emission Factors**

Previous Inventory CO <sub>2</sub> Emission Factor		Draft Inventory Emission Factor (scf CO <sub>2</sub> /mbl refinery feed)	
Asphalt Blowing	20,736 scf CO <sub>2</sub> /mbl 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 CH<sub>4</sub> and CO<sub>2</sub> are compared separately. The impact of the new CH<sub>4</sub> factors is an increase of CH<sub>4</sub> emissions for years across the time series that ranges from 40 to 80 percent. The impact of the new CO<sub>2</sub> factors is an increase in CO<sub>2</sub> emissions for years across the time series by two orders of magnitude.

**Table 5. Impact of Revised Emission Factors--2014 and 2015 Inventory Estimates for Petroleum Refineries**

	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>	<b>2013</b>
2014 Inventory (MT CH <sub>4</sub> )	17,622	18,055	19,277	19,342	18,586	N/A
2015 Inventory (MT CH <sub>4</sub> )	27,493	28,650	30,976	31,206	26,807	33,964
2014 Inventory (MT CO <sub>2</sub> )	17,981	18,686	21,080	20,478	15,265	N/A
2015 Inventory (MT CO <sub>2</sub> )	4,070,108	4,241,363	4,585,706	4,619,709	3,835,619	5,540,353