



Summary of Expert Review Comments and Responses:  
*Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020*

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# Responses to Comments Received during the Expert Review Period on the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020*

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## Preface

EPA thanks all commenters for their interest and feedback on the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks. To continue to improve the estimates in the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks, EPA distributed draft chapters of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020* for a preliminary Expert Review of estimates and methodological updates prior to release for Public Review. The Expert Review ranged from 30 days by sector and included charge questions to focus review on methodological refinements and other areas identified by EPA as needing a more in-depth review by experts. The goal of the Expert Review is to provide an objective review of the Inventory to ensure that the final Inventory estimates, and document reflect sound technical information and analysis. Conducting a basic expert peer review of all categories before completing the inventory in order to identify potential problems and make corrections where possible is also consistent with IPCC good practice as outlined in Volume 1, Chapter 6 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

EPA received 78 unique comments on as part of the Expert Review process. The verbatim text of each comment extracted from the original comment letters is included in this document, arranged by sectoral chapters. EPA's responses to comments are provided immediately following each comment excerpt. The list of reviewers, dates of review and all charge questions distributed to reviewers are included in the Annex to this document.

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# Chapters 1. Introduction and 2. Trends

*Chapters 1 and 2 were not sent out for expert review given they include only summary information and synthesize information from chapters 3-7 rather than presenting or providing underlying technical information.*

## Chapter 3. Energy

*No comments received on the Energy chapter.*

## Chapter 4. IPPU

### **Comment 1: Question on Site Producing FeMn**

I thought Marietta Eramet OH was still actively producing FeMn, but the section on ferroalloys only have FeSi.

*Response: As noted in the final Inventory report on p. 4-92, “Emissions from the production of...ferromanganese are not included [in the Inventory] because of the small number of manufacturers of these materials in the United States. Government information disclosure rules prevent the publication of production data for these production facilities” because only 1 facility in the United States produces ferromanganese. EPA will explore ways to incorporate data from these ferroalloy facilities as reported to GHGRP.*

### **Comment 2: Question on Uncertainty Estimate**

What statistical distribution is assumed for the Monte Carlo uncertainty estimate?

*Response: The Monte Carlo uncertainty analysis for ferroalloy production uses a normal distribution for activity data (e.g., the amount of ferroalloys produced) and a triangular distribution for emission factors and other factors like heat and carbon content values.*

### **Comment 3: Phosphate rock imports**

Page 4-26, line 11: Recommend changing to “imports of phosphate rock to the United States in 2020 were estimated to be approximately 2.3 million metric tons 11 (USGS 2021a)”.

*Response: EPA updated text on p. 4-77 of the final Inventory report.*

### **Comment 4: Change in domestic phosphoric acid production**

Page 4-26, line 16: I get 31% (referring to decrease in domestic phosphoric acid production from 1990 to 2020):

- 1990: 9,026,000 metric tons
- 2020: 6,240,000 metric tons

*Response: EPA clarified in the final Inventory report that the rate of change is related to domestic phosphate rock production, on p. 4-77. EPA will also explore the domestic phosphoric acid production data provided.*

**Comment 5: Domestic sales of phosphate**

Page 4-27, line 14:– based on production capacity.

***Response: EPA updated text on p. 4-78 of the final Inventory report.***

**Comment 6: Florida Institute of Phosphate Research**

Page 4-27, line 21: The Florida Institute of Phosphate Research is now called the “Florida Industrial and Phosphate Research Institute.”

***Response: EPA updated text on p. 4-77 of the final Inventory report.***

**Comment 7: Location name on Table 4-21**

Page 4-27, Table 4-21: Recommend changing “U.S. Domestic Consumption” rows to “Domestic reported sales and use of phosphate rock”.

***Response: EPA notes that text on p. 4-78 of the final Inventory report explain the use of data for domestic sales or consumption of phosphate rock in this methodology. EPA will consider ways to more clearly describe the data displayed in Table 4-57 in the next Inventory report.***

**Comment 8: Values in Table 4-21**

Page 4-27, Table 4-21: Estimates for regional consumption should be rounded. Recommend rounding the 2020 values for “FL and NC” and “ID and UT” to 19,000 and 5,000, respectively; updating imports to 2,520; and recalculating total as 25,100 to include updated import data.

***Response: EPA rounded the “FL and NC” and “ID and UT” values for years where the value was calculated instead of reported. See p. 4-79 for the updated Table 4-57. EPA uses import values as reported in USGS publications and will update values for the next Inventory report.***

**Comment 9: Use of ferroalloys**

Page 4-30, line 22: I think this could be reworded to clarify. Ferroalloys are produced in conjunction with the iron & steel industry, usually at co-located facilities, however, the way this is worded seems to imply ferroalloys are consumed in iron & steel production. Ferroalloys is a generalized term to include the outputs of specialty alloys for use in end-use applications such as aerospace, defense, electrical, and industrial manufacturing.

***Response: EPA updated text on p. 4-92 of the final Inventory report.***

**Comment 10: Use of term “ferroalloy”**

Page 4-32, line 1: Change “ferroalloy production” to “silicon production.”

***Response: EPA used all publicly available data on ferroalloy production. As noted on p. 4-92 of the final Inventory report, data on the quantity of other ferroalloys, including silicon (metals), produced in the United States are not available due to government information disclosure rules used by USGS. EPA did not make this change at this time. EPA will assess whether process emissions and other data reported to GHGRP by ferroalloy facilities can be used to improve the Inventory.***

**Comment 11: Silicon metal production**

Page 4-32, line 8: It might be useful to mention that the reason silicon metal was not available was related to disclosure rules.

**Response: EPA updated text on p. 4-94 of the final Inventory report.**

**Comment 12: Publications on ferroalloy production**

Page 4-32, line 12: Take a look at the Ferroalloys Chapter in the Minerals Yearbook. We also produce noble ferroalloys in the U.S. We report bulk and noble ferroalloy production in the Ferroalloys chapter. Go to [https://www.usgs.gov/centers/nmic/ferroalloys-statistics-and-information?qt-science\\_support\\_page\\_related\\_con=0#qt-science\\_support\\_page\\_related\\_con](https://www.usgs.gov/centers/nmic/ferroalloys-statistics-and-information?qt-science_support_page_related_con=0#qt-science_support_page_related_con) for that information. At the very least, it seems like the other ferroalloys should be incorporated into the discussion more or more information could be provided on how we report other ferroalloy production.

**Response: EPA updated and clarified text on p. 4-92 of the final Inventory report which elaborates on the production of ferrochromium and ferromanganese in the United States during the 1990-2019 time series. EPA will also assess whether the production processes for other ferroalloys process emit greenhouse gases and, because production data is not available due to government information disclosure rules used by USGS, the process emissions and other data reported to GHGRP by ferroalloy facilities.**

**Comment 13: Use of term “ferroalloy”**

Page 4-32, line 12: You mean ferrosilicon, not ferroalloy. There is a ferroalloy mineral yearbook that reports bulk and noble ferroalloy production. See Table 1 in <https://prd-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb1-2017-feall.pdf>.

**Response: See response to comment #10.**

**Comment 14: Use of term “ferroalloy”**

Page 4-32, line 13: Change “ferroalloy” to “silicon.”

**Response: See response to comment #10.**

**Comment 15: Use of term “ferroalloy”**

Page 4-32, line 14: Change “ferroalloy” to “silicon.”

**Response: See response to comment #10.**

**Comment 16: Review Ferroalloy Mineral Yearbook**

Page 4-32, line 15: I recommend looking at the 2017 Ferroalloy Mineral Yearbook. It includes ferromanganese information as well as ferrosilicon. If you are using only ferrosilicon data, be consistent. It's misleading to refer to ferroalloy production when you really mean ferrosilicon production.

**Response: EPA used publicly available data on ferroalloy production, and as noted on p. 4-92 of the final Inventory report, data on the quantity of ferromanganese produced in the United States are not available due to government information disclosure rules used by USGS. EPA did not make this change at this time.**

**Comment 17: Table 4-26 title**

Page 4-32, line 18: Change table title to “Production of Silicon”

**Response:** See response to comment #10.

**Comment 18: Use of term “ferroalloy”**

Page 4-32, line 22: Change “ferroalloy” to “silicon.”

**Response:** See response to comment #10.

**Comment 19: Use of term “ferroalloy”**

Page 4-32, line 25: Change “ferroalloy” to “silicon.”

**Response:** See response to comment #10.

**Comment 20: U.S. aluminum production**

Page 4-34, line 8: This is correct. The US was ninth leading producer and all countries listed in "other" produced less than the US.

**Response:** EPA notes confirmation of information on U.S. production in the context of global production included in the Inventory report.

**Comment 21: Decline in aluminum production**

Page 4-35, line 11: Using 1012 for 2020 production, decline is 75%. (See note in table 4-33 about production data.) Suggest using USGS data as noted in table 4-33 note; update percentage calculations.

**Response:** EPA did update production estimates using USGS production totals instead of USAA production totals for 2018-2020 in Table 4-84. See also the updated discussion of production data on pages 4-98 and 4-101.

**Comment 22: 2020 U.S. primary aluminum production**

Page 4-35, line 18: USGS December 2020 Mineral Industry Survey reports 1.012 million metric tons in 2020. This is 7% less than production in 2019 according to USGS data in 2021 Mineral Commodity Summary.

**Response:** See response to comment #21.

**Comment 23: Discrepancy in primary aluminum production data reported by USGS**

Table 4-33: The USAA data for 2018, 2019, and 2020 are different from what is reported by USGS because one company (Magnitude 7 Metals) is estimated by USAA but it reports actual data to USGS. The totals that USGS reports are 2018= 891; 2019= 1093; and 2020= 1012. These data are reported in the 2021 Mineral Commodity Summary (for 2018 and 2019 data) and in the December 2020 Mineral Industry Survey for 2020 data. See <https://www.usgs.gov/centers/nmic/aluminum-statistics-and-information> for these reports.

**Response:** See response to comment #21.

**Comment 24: Subscript “2” in CO<sub>2</sub>**

Page 4-41, line 1: Change the “2” to a subscript.

**Response:** EPA did correct formatting of “2” so it is presented as a subscript on page 4-103.

**Comment 25: Magnesium Production and Processing section**

Page 4-41, line 9: I have no comments concerning data in the magnesium section. The information appears to be accurate and reliable. I can not offer an opinion on the calculation methods for cover gas consumption rate by process. My only comments are on typos.

**Response:** *EPA appreciates reviewer's perspectives and notes reviewer had no additional feedback.*

**Comment 26: Fix wording in magnesium section**

Page 4-41, line 28: "Attributed," not "contributed."

**Response:** *EPA edited the sentence as suggested on page 4-104.*

## Chapter 5. Agriculture

*No comments received on the Agriculture chapter.*

## Chapter 6. LULUCF

**Comment 27: 6.2, 6.10 Net Carbon Stock Exchange**

EPA estimates net carbon stock exchange for materials in landfills within two categories. Harvest wood products are classified under "Forest Land Remaining Forest Land" and yard waste and food scraps under "Settlements Remaining Settlements." Additional carbon storage sources that exist within landfill are unfortunately not included, such as textiles (which include natural sources such as cotton, wool, and silk as well as synthetics) and rubber (which can be natural or synthetic), and leather. These products represent more than 10% of the materials landfilled and while they are organic sources, they tend to decompose very slowly within a landfill environment. EPA should account for these additional materials within "Cropland Remaining Cropland."

**Response:** *This feedback has been added as a planned improvement to the Landfilled Yard Trimmings and Food Scraps category. However, EPA disagrees with the comment to include these sources of carbon within 'Croplands Remaining Croplands' and will plan to include under 'Settlements Remaining Settlements' since landfills are associated with the Settlements land type.*

**Comment 28: Table numbers not corresponding with table references in text**

I assume this is already known since this is a draft document, but the table #s do not match the table #s in the text (e.g., 6-18, L20 cites Table 6-17 but it should be citing Table 6-15).

**Response:** *EPA updated the Table numbering in the final Inventory report.*

**Comment 29: Change in Land Area vs. Amount of Forest Land**

Page 6-5, Lines 17-19. Consider breaking this sentence into two, since two ideas are presented here: change in land area and region with the largest amount of forest land.

**Response:** *EPA evaluated the feedback to split text into two sentences to focus on change in land area and forest areas but plans to keep the sentence as written to continue to emphasize the point that these topics as a whole contribute to the overall C stock balance in the Forestland Remaining Forestland category.*



**Comment 30: Clarification on what “Histosols” is referring to**

Page 6-13, Line 1. ‘...and organic soils, the latter also referred to as Histosols’

***Response: EPA incorporated the edit and reflected the clarification on page 6-35 of the Final Inventory report.***

**Comment 31: Replacing “carbons” with “carbon”**

Page 6-32, Line 2. ‘carbon’

***Response: EPA addressed the typo and the correction is reflected on page 6-54 of the Final Inventory report.***

**Comment 32: Suggestion on improving clarity**

Page 6-34, Lines 3-6. The way this is written is confusing as it seems to suggest that emissions only from ‘extraction’ are estimated (rather than the multiple processes listed).

***Response: The commenter is reading the text correctly, emissions from managed peatlands during the production cycle are estimated only from the extraction phase within this specific section of Peatlands Remaining Peatlands. EPA is considering how best to update the text to improve the clarity in future Inventories.***

**Comment 33: Lack of clarity on use of the word “biomass”**

Page 6-34, Lines 7-8. Does ‘biomass’ refer to vegetation here? Or peat? Or both?

***Response: The ‘biomass’ reference in this sentence is referring to peat. EPA is considering how best to update the text to clarify in future Inventories.***

**Comment 34: Grammatical correction on word “Sphagnum”**

Page 6-34, Line 28 (and elsewhere). Sphagnum should be capitalized and italicized.

***Response: EPA incorporated the correction on pages 6-93 and 6-95 of the Final Inventory report.***

**Comment 35: Suggestion for restructuring section for clarity**

Page 6-42, Lines 5-7. It would be helpful to provide this information (i.e., all coastal wetlands are included) at the start of the Coastal Wetlands Remaining Coastal Wetlands section.

***Response: EPA is considering how best to update the text to clarify in future Inventories.***

**Comment 36: Suggestion on word change to avoid statistical confusion**

Page 6-43, Line 15. Is there a specific definition to the word ‘significant’? If not, suggest using a different term as it can be confused with the statistical usage.

***Response: EPA incorporated the suggestion by removing the word ‘significant’ and it is reflected on page 6-102 of the Final Inventory report, page 6-102.***

**Comment 37: Repeated table reference typo**

Page 6-51, Line 7. Table 6-69 listed twice in a row.

***Response: EPA removed the typo and the correction is reflected on page 6-105 of the Final Inventory report.***

**Comment 38: Date typo**

Page 6-56, Line 36. Typo (20220).

***Response: EPA corrected the date typo on page 6-114 of the Final Inventory report.***

**Comment 39: Question on disaggregating water bodies across country borders**

Page 6-63, Line 14. What about water bodies that cross country borders (Mexico, Canada)? I assume those are disaggregated in the same way as waterbodies that cross state lines? Along those lines, if a reservoir crosses a state boundary with the outlet in another state, I assume the downstream emission estimate would apply to the state where the outlet was located? It might be worth mentioning this here.

***Response: EPA agrees that clarification on disaggregation of water body boundaries that cross country borders and has added details on how this is addressed on page 6-120 of the final Inventory report.***

**Comment 40: Suggestion for removal of language for accuracy**

Page 6-69, Line 28. Remove 'and climate zone' as canals/ditches and ponds were not analyzed by climate zone.

***Response: EPA agrees and clarified that waterbodies are disaggregated only by state in text on page 6-127 of the final Inventory report.***

**Comment 41: Question on definition of "substantial change"**

Page 6-80, Lines 13-14. How is a 'substantial change' in water surface area defined and is this change in water surface area only assessed when the reservoir was not included in the NW database (6-84 L11-12 mentions that all reservoirs in the NW dataset were considered managed flooded lands)?

***Response: EPA agrees, and further explanation of how this determination of "substantial change" was made was included in the Public Review version on page 6-140 and page 6-141 of the final Inventory report.***

**Comment 42: Suggestion on renaming table title**

Table 6-98. 'CH4 methane' in table title; remove one.

***Response: EPA agrees and has removed the duplication of text within Table 6-96 on page 6-140 of the final Inventory report.***

**Comment 43: Potentially unnecessary repetition in language**

Page 6-84, Line 18-20. Are these sentences needed in this section (L18-19 is very similar to L11-12)?

***Response: EPA has updated text to clarify the assumptions identified by the commenter on page 6-141 of the final Inventory report.***

**Comment 44: Question on methane emission factor use**

Page 6-90, Line 12. I believe that the emission factor for CH<sub>4</sub> in Table 6-107 is for 'Land remaining flooded land - other waterbodies', not 'land converted to reservoirs' as stated (the latter had a variable emission factor by climate zone). Which was used in this analysis?

**Response:** EPA notes that the Expert Review draft Table 6-107 and calculations were correct, but the text was incorrect. EPA has made updates to the text on page 6-148 of the final Inventory report.

**Comment 45: Yard Waste & Food Scraps Category**

Is the state of the sector current and accurately described? Are there other technologies, practices, trends that we should consider? Are there other data sources that EPA should be aware of and consider in the calculating these emissions? Especially for:

- C storage, decay rates, etc. for yard trimmings and food scraps
- Decay rates of food scraps, leaves, grass, and branches
- National yard waste compositions
- Precipitation range percentages for populations for the decay rate sensitivity analysis

We do not have any data to provide regarding yard waste and food scraps. However, given that yard waste composting programs and mulching mowers are more common, we believe that the composition of yard waste is likely to contain more branches and less grass.

**Response:** EPA notes the trends shared by the commenter. EPA continues to assess and review data sources and to more completely reflect additional sources of carbon within this category. For example, please see response to comment #27.

**Comment 46: Final general comments on LULUCF chapter**

Overall, the chapter was clearly written, and I only had a couple of comments in the flooded land section where additional methodological description would be helpful (see detailed comments below). The methodologies applied to this chapter (specifically the flooded land sections of this chapter, where my expertise lies) appear appropriate given the available data.

Regarding data sources for the flooded lands section, the data used appears appropriate given current data availability. One dataset that may be of use (not yet released) in future inventories is the LAGOS dataset: <https://lagoslakes.org/lagos-us-overview/> (reservoirs). Another (although this appears to already be captured in the inventory) is the HILARRI dataset: <https://hydrosources.org/dataset/hydropower-infrastructure-lakes-reservoirs-and-rivers-HILARRI>

**Response:** EPA appreciates the information on additional data sources. Please see responses to other comments below.

**Comment 47: Comment on organic matter decomposition**

6-34, line 24-25: The organic matter is still decomposed but at a slow rate because the lack of oxygen, said that, the decomposition process does not stop.

**Response:** EPA understands decomposition is occurring and the sentence aims to reflect that "normal" decomposition is no longer occurring at this point. EPA is considering how best to update the text to clarify in future Inventories.

**Comment 48: Note to add reference to value**

6-35, line 6-7: It would be important to add a reference to the 94% percent.

**Response:** *EPA notes that this 94 percent reflects the current analysis. EPA is considering how best to update the text to clarify and/or add more specific references in future Inventories.*

**Comment 49: Comment on standard deviation inclusion**

6-35, line 11: I wonder if it is possible to add the standard deviations (SD) to the values or at least highlight these values in text. I think this is important because the difference that is highlighted between 2019 and 2020 is 0.1 MMT, but if SD is the same value (for example), then is it real this 6.2 percent of difference?

**Response:** *EPA will consider how best to update the text to clarify in future Inventories while balancing the need for consistency across chapter/category text.*

**Comment 50: Request for further explanation for Changes**

6-35, lines: 12-23: Two questions for this paragraph: for each explanation of changes, is it possible to show a possible reason for those changes? or this could be highlighted along the document? This description uses years that are not showed in table 6-45 or 6-46. I wonder if it is possible to include that information on tables or if it is not possible briefly say why this information is not in tables, but it is discussed in the document.

**Response:** *EPA will consider how to best update the text and/or tables to clarify in future Inventories while balancing the need for consistency across chapter/category tables.*

**Comment 51: Highlight relevant data in paragraph along with table**

6-35, Table 6-45. It is highlighted in tables that numbers are based on the U.S production data, maybe also highlight the same information at the beginning of the paragraph on line 12.

**Response:** *EPA is considering this text change, among others, as part of larger text updates to this category in future Inventories.*

**Comment 52: Suggestion of including the conversion factor**

6-36, line 7: Maybe include the conversion factor in (), so the reader can have an immediate idea about it.

**Response:** *EPA is considering this text change, among others, as part of larger text updates to this category in future Inventories.*

**Comment 53: Comment of validity of data based on time taken**

6-37, line 24-26: It would be good to know when the USGS stated that the number of operations has been declined since 1990, if the reference has more than 10 years, I would suggest not to assume that there are no new areas of vegetation cleared for peat extraction. It may not be a net change in the area, but what about the recuperation of some areas without intervention and the potential clearance of new ones.

**Response:** *EPA is considering this text change, among others, as part of larger text updates to this category in future Inventories. As noted by the commenter, it would not change the current methodology but provide clarification.*

**Comment 54: Question on factors**

6-38, lines 7-8: Are these factors already included in the previous chapter? or an annex? There may be readers that would like to see them or have access to these factors instead to go to the reference.

***Response: EPA is considering this text change, among others, as part of larger text updates to this category in future Inventories.***

**Comment 55: Confusion on Table reference**

6-38, line 15-16: It is unclear to me why this sentence is referring Table 6-54 where there are not CH<sub>4</sub> emission data on that table.

***Response: EPA has made corresponding updates to page 6-97 of the Final Inventory report.***

**Comment 56: Comment on previous point**

6-39, line 26-28: This confirms my point in 6-35, line 11, about the differences highlighted in percentages from 2019 to 2020. Under the information in these lines there are not differences.

***Response: See response to comment #50.***

**Comment 57: Suggestion to highlight QA/QC steps**

6-40, line 1: Maybe highlight the steps followed for the QA and QC, for example, removal of outliers, threshold values, gap filling, etc.

***Response: EPA is considering this text change, among others, as part of larger text updates to this category in future Inventories. In particular, EPA is assessing how best to provide additional details on the QA/QC steps undertaken, both general and category-specific.***

**Comment 58: Discrepancy in highlighted pools**

6-41, line 27: Here is highlighted 5 pools but the information in parentheses is 4 pools.

***Response: EPA notes that the 5 specific carbon pools are included, but will assess how best to update the text in future Inventories to clarify.***

**Comment 59: Suggestion to rephrase based on recent studies**

6-41, line 29-30: I suggest rephrasing this, because recent studies have shown that not all the coastal wetlands are net sink of C (Vazquez-Lule and Vargas 2021; Liu et al., 2020).

***Response: EPA made edits rephrasing findings from recent studies on page 6-100 of the final Inventory report.***

**Comment 60: Suggestion to rephrase text on respiration**

6-41, line 31-32: Emission of C are not just a response to changes, wetlands ecosystems are alive even without land cover changes. These ecosystems take CO<sub>2</sub> from the atmosphere and emit CO<sub>2</sub> to the atmosphere as a regular ecosystem process. I would suggest rephrasing this because respiration (CO<sub>2</sub> emission) happens everytime as a regular ecosystem activity.

***Response: EPA made edits rephrasing text on respiration on page 6-100 of the final Inventory report.***

**Comment 61: Highlight carbon storage timeline**

6-41, line 34-35: May be before to say this, highlight that the carbon stored in coastal wetlands soils is from decades to thousands of years.

***Response: EPA made edits to clarify the carbon storage timeline on page 6-100 of the final Inventory report.***

**Comment 62: Clarifying Process**

6-41, line 36: This process can be natural or by restoration activities.

***Response: EPA made edits to reflect this clarification on page 6-100 of final Inventory report.***

**Comment 63: Suggestion to rephrase sentence for clarity**

6-41, line 37-39: This sentence is complicated to follow, I think what you want to say is that coastal wetlands under higher salinity conditions tend to have lower CH<sub>4</sub> emissions compared with coastal wetlands under lower salinity conditions (such as brackish) and freshwater wetlands.

***Response: EPA rephrased this sentence for clarify on page 6-100 of the final Inventory report..***

**Comment 64: Suggestion to reevaluate assumption on methane emissions**

6-41, line 39-41: It has been assumed that CH<sub>4</sub> emission are lower because a higher concentration of sulphate in soils (that is indirectly related with salinity conditions), however recent studies have shown that methane emissions can happen via other methanogenesis pathways (i.e., methylotrophic methanogenesis). Said that, it means that production of methane in high sulfate soils happens as a response of the organic matter decomposition produced in situ (Sayfferth et al., 2020). It is unknown if these changes can impact or not methane emissions. I would suggest being more conservative with these assumptions.

***Response: EPA made edits to be more explicit in that our assumptions are conservative in the final Inventory report, page 6-100.***

**Comment 65: Discrepancy in table**

6-42, line 12-24: I think the table 6-56 is not the table used in the paragraph. This paragraph requires consistence between description and table values and their signs.

***Response: EPA corrected text to update the table reference and the correction is reflected on pages 6-100 and 6-101 of the final Inventory report.***

**Comment 66: Suggestion on clarifying positive and negative values' meaning**

6-42, line 13: When you are highlighting these negative values, it is possible the reader cannot understand why you said they are sink and why numbers are negative. You may add a statement something like this: In this report negative values represent the carbon uptaked from the atmosphere by the ecosystems, while positive values represent emission of carbon from the ecosystems to the atmosphere. You highlight negative values here, but when you see Table 6-53 those values are not negative, I would suggest being consistent about how values are presented.

***Response: EPA has not made edits based on this comment to ensure consistency with other categories in the Inventory. As noted in the tables, "Parentheses indicate net sequestration.", or a negative values, consistent with chapter text.***

**Comment 67: Table Discrepancy**

6-42, line 20-21: This description does not directly match with data in table 6-53. Please check the sign of each value in the description and table.

**Response:** *EPA has not made edits as the text matches the values within the table.*

**Comment 68: Comment on dwarf mangroves**

6-43, line 7: I think Florida also has dwarf mangroves, please double-check if it is needed to include it as well.

**Response:** *EPA made edits to reflect types of mangroves in all subtropical states along the Gulf Coast region on page 6-101 of the final Inventory report.*

**Comment 69: Comment on considering allochthonous carbon**

6-43, line 12 “removal of atmospheric CO<sub>2</sub> by vegetation”: It is not just that, it is also the consequence of the input of allochthonous carbon (carbon imported by water from high watershed areas and coastal areas) and retained and buried in the coastal wetlands’ sediments. So, this means contributions from autochthonous carbon (by vegetation, in situ) and by allochthonous carbon (carbon imported into the ecosystem).

**Response:** *EPA made edits to reflect the transfer of both autochthonous and allochthonous decaying organic matter on page 6-101 of the final Inventory report.*

**Comment 70: Reference back to previous comment on soil respiration**

6-43, line 14: Please see previous comments, soils respire every time, so they emit CO<sub>2</sub> by aerobic decomposition and CH<sub>4</sub> by anaerobic decomposition, even with vegetated coverages.

**Response:** *EPA has not made edits to the text on page 6-102 of the Final Inventory as this sentence is discussing methane emissions specifically. This inventory is created using emissions factors and activity data and the fluxes are not calculated using process-based models that specifically include plant and soil respiration. The emissions factors used for coastal wetland plants and soils incorporate the daily fluxes*

**Comment 71: Comment on clarity between values and tables**

6-43, line 17-32: It is hard to follow the description with the values and the table referred because they are not consistent. I would suggest to double check this in all the text.

**Response:** *EPA made edits to reflect updated table references in the final Inventory report, page 6-102.*

**Comment 72: Comment on consistency between meaning of positive and negative values**

6-43, Table 6-54: As you previously did, you used negative values to highlight sinks of carbon and now if you use just use positive values for sinks, readers can get confused. Try to homologate what you plan to use along the text and tables.

**Response:** *EPA has not made edits based on this comment to ensure consistency with other categories in the Inventory.*

**Comment 73: Reference to previous comment**

6-47, Table 6-61: Same comment than 6-43, Table 6-54.

**Response: EPA has not made edits based on this comment to ensure consistency with other categories in the Inventory.**

**Comment 74: Reference to previous comment**

6-49, Table 6-63: Same comment than 6-43, Table 6-54.

**Response: EPA has not made edits based on this comment to ensure consistency with other categories in the Inventory.**

**Comment 75: General comment on LULUCF chapter**

Sections in general follow a similar structure that is good for the purpose of comparison, however some sections have a more detailed description on the QA and QC and some others may need more detail (see comments below). In some parts of the text when you are referring specific values or percentages, it may be needed to add the corresponding references. One of my mayor suggestions is to review the consistence of tables referred in text and the number of tables, I found that many of them are not consistent. There are some parts in the text that I suggest being more conservative about statements (e.g., highlighting that coastal wetlands are net sinks of carbon), because those areas are at the frontier of knowledge and the scientific community is still discovering new results.

**Response: Each source and sink category in LULUCF is unique and in some cases multiple methods (e.g., IPCC Tier 1, 2 or 3) are used to estimate the fluxes from a given category. Because of this variability, there will be differences in the amount and type of information presented in the QA/QC descriptions. EPA will consider how best to update and improve consistency of the QA/QC descriptions across categories in the LULUCF chapter for future Inventories.**

## Chapter 7. Waste

**Comment 76: RTI Scale-Up Factor Memo**

The RTI 2021 Scale up factor memo indicates that waste-in-place is approximately 7% and 11% utilizing a 30-year and 50-year outlook respectively. We understand that EPA plans to utilize the 50-year period because the 2006 IPCC Guidelines recommends it. While we recognize that landfill gas can be produced for a long time, this methodology does not adjust for the non-linearity of methane production. Given the first order decay model, methane production for a given amount of waste declines with each passing year. We recommend that EPA account for this nonlinearity especially given that 30% of the total WIP is more than 30 years old.

**Response: EPA will further investigate how best to account for the non-linearity of methane production and emissions from MSW landfills that do not report to the GHGRP, including using the FOD model for these landfills based on estimated annual waste disposed for this subset of landfills between 2005 to 2020, reverting to the total waste-in-place approach, or modifying the time-based threshold approach.**

**Comment 77: Suggestion to rephrase sentence for accuracy**

Based upon discussions between EPA, ERG and NCASI in early 2021 regarding receiving water types for US pulp and paper facility effluent discharges, the following information was incorporated into the draft “The percent of pulp, paper, and paperboard wastewater treatment effluent routed to reservoirs, lakes, or estuaries (3 percent) and other waterbodies (97 percent) were obtained from discussions with NCASI (ERG



2021b).” NCASI provided Table 1 to ERG and EPA on pulp and paper effluent discharges by destination. It may be more appropriate to reword the sentence on effluent disposition to “The percent of pulp, paper, and paperboard wastewater treatment effluent routed to estuaries (3 volume percent) and other waterbodies (97 volume percent) were obtained from discussions with NCASI (ERG 2021b).”

Table 1. US Pulp and Paper Process Effluent Discharges by Destination

Destination Type	Process Water (Volume %)
River or Lake	86%
Municipal	7%
Ocean	3%
Other	4%

**Response:** EPA thanks the reviewer for their comments and may require follow up to further clarify any data representation concerns. On 2/5/2021, EPA received clarification to the data presented in Table 1, breaking down the ‘River and Lake’ category (86%): “The pulp and paper effluent discharge volume % to rivers is 83% and the volume % to lakes is 3%.” Therefore, the 3 percent used within the pulp and paper wastewater calculations is associated with the supplemented data for Lakes, rather than any values provided in the original table. For consistency, EPA refers to any discharges to these waterbodies as “reservoirs, lakes, or estuaries” throughout the chapter text.

**Comment 78: Suggestion on study for methane emissions value from landfills**

Annex 3.14 provides detailed methodology for estimating methane emissions from landfills. Within the Annex, Step 8a discusses estimates of methane oxidation from industrial landfills. It is correctly noted that oxidation rates from industrial landfills are highly variable, ranging from zero to over 100%. NCASI recommends citing the article by Chanton et al., who provided a review of methane oxidation in landfill cover soils (2009)<sup>1</sup>. They determined that the overall mean fraction of methane oxidized across 42 reviewed studies was 36% with a standard error of 6%. NCASI recommends that the variability in landfill oxidation percentages be incorporated into the calculations around uncertainty estimates for methane emissions from landfills (to be included in Table 7-5).

**Response:** EPA completed a literature review of methane oxidation in landfills in 2017 that is referenced in Annex 3.14 as “RTI 2017b.” EPA included the 2009 Chanton et al. article in this review. The focus of this literature review was to evaluate revising the oxidation factor for non-reporting landfills for years 1990-2004. For the other years of the time series the oxidation value is included in net emissions reported through GHGRP. Variability of oxidation is included in the uncertainty calculations, the final results of which are included in Table 7-5.

<sup>1</sup> Chanton, J.P., Powelson, D.K., Green, R.B. 2009. Methane oxidation in landfill cover soils, is a 10% default value reasonable? Resources, Conservation and Recycling 150:104415.

# Appendix A: List of Reviewers and Commenters

EPA distributed the expert review chapters of the draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020* to a list of 265 expert reviewers across all sectors of the Inventory. The list below includes names of those expert reviewers who submitted comments as part of the Expert Review Period.

- Jesse Maxwell – Solid Waste Association of North America (SWANA)
- Natalie Griffiths – Oak Ridge National Laboratory (ORNL)
- Darrell Smith – National Waste & Recycling Association
- Antoine Allanore – Massachusetts Institute of Technology
- Alma Vazquez-Lule – National Oceanic and Atmospheric Administration
- Barry Malmberg – National Council for Air and Stream Improvement
- “S. Jasinski, C. Tuck, L. Bray, R. Schulte” - National Minerals Information Center, US Geological Survey (USGS)

*Note: Names of commenters are listed in no particular order.*

## **Appendix B: Dates of Review**

- Energy: November 9, 2021 – December 9, 2021
- Industrial Processes and Product Use (IPPU): November 1, 2021 – December 1, 2021
- Agriculture: November 2, 2021 – December 2, 2021
- Land Use, Land Use Change and Forestry (LULUCF): November 9 – December 9, 2021
- Waste: October 27, 2021 – November 30, 2021

# Appendix C: EPA Charge Questions to Expert Reviewers

To facilitate expert review and indicate where input would be helpful, the EPA included charge questions for the Expert Review Period of the draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020* report. EPA also noted to expert reviewers that while these charge questions were designed to assist in conducting a more targeted expert review, comments outside of the charge questions were also welcome. Included below is a list of the charge questions by Inventory chapter.

## Energy

### Requests for Expert Feedback for the 1990-2020 Energy Chapter

#### **General Questions:**

1. Please provide your overall impressions of the clarity and transparency of the Energy chapter.
2. Please provide any recommendations that EPA can consider for improving the completeness and/or accuracy of the Energy chapter.
3. Please provide any information on data sources available with regional or other disaggregated information on energy use or emissions.

#### **Fossil Fuel Combustion: CO<sub>2</sub> from Fossil Fuel Combustion**

1. Please provide your overall impressions of the clarity of the discussion of trends in CO<sub>2</sub> emissions from fossil fuel combustion. Please provide recommendations for any information that could be added to the discussion to provide additional transparency and clarity.
2. Data for energy use in U.S. Territories comes from updated International Energy Statistics provided by EIA. Are the updates adequately described and do they compare to any other sources of U.S. Territory energy use that could be used?
3. Facility-level combustion emissions data from EPA's GHGRP are currently used to help describe the changes in the industrial sector. Are there other ways in which the GHGRP data could be used to help better characterize the industrial sector's energy use? Are there ways the industrial sector's emissions could be better classified by industrial economic activity type?

### ***Fossil Fuel Combustion: CH<sub>4</sub> and N<sub>2</sub>O from Stationary Combustion***

1. The CH<sub>4</sub> and N<sub>2</sub>O emission factors for the electric power sector are based on a Tier 2 methodology, whereas all other sectors utilize a Tier 1 methodology. For all other stationary sectors, the emission factors used in Tier 1 methods are primarily taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Are there other more U.S.-specific CH<sub>4</sub> and N<sub>2</sub>O emission factor data sources that could be utilized, especially for natural gas combustion sources?

### ***Carbon Emitted from Non-Energy Uses of Fossil Fuels***

1. Please provide your overall impressions of the clarity of the discussion of Carbon Emitted from Non-Energy Uses of Fossil Fuels. Please provide recommendations for any information that could be added to the discussion to provide additional transparency and clarity, especially in relation to linkages with the estimates in the IPPU chapter.

### ***Fugitive Emissions***

1. Please provide your thoughts on the proposed approach for adding methods for CO<sub>2</sub> fugitive emissions from coal mining. The approach is outlined in the attached memo and referenced in the text of the ER active coal mining draft, in the Planned Improvements section.

## **Industrial Processes and Product Use (IPPU)**

### **Requests for Expert Feedback for the 1990-2020 IPPU**

#### **Chapter General Questions:**

1. Please provide your overall impressions of the transparency of the IPPU chapter.
2. For the source categories included in the expert review draft, is the state of the industry current and accurately described? Are there technologies, practices, or trends that EPA should consider?

#### **Source-Specific**

##### **Questions: Minerals**

1. **Glass Production** – See supporting technical memo on improvements titled “Glass\_production\_improvement\_memo”. Please provide feedback or information on the following updates:
  - This is the first year that data from GHGRP and the Federal Reserve Industrial Production index were used to calculate emissions for the full time series, 1990-2020. Please provide any recommendations to improve the transparency, accuracy, consistency, and/or completeness of the estimation methods.
  - Data sources on limestone, dolomite, and soda ash (carbonates) used for glass manufacturing by glass operations that could improve the completeness of emissions estimates from glass production, accounting in particular for facilities that fall below

the GHGRP reporting threshold of 25,000 metric tons CO<sub>2</sub>e, nationally and by state.

- In this Expert Review draft, GHGRP data on soda ash used for glass production is used to calculate emissions. Please provide any recommendations on whether USGS data on soda ash used for glass production is a more complete national dataset, perhaps given the structure of the soda ash production industry.

## Chemicals

2. **Glyoxal and Glyoxylic Acid Production** – Please provide feedback or information:
  - Based on data reported to EPA for TSCA, it appears that glyoxal may be produced domestically at up to 4 facilities and that all glyoxylic acid used in the U.S. may be imported. Please share any information about these facilities, including whether they use gas-phase catalytic oxidation of ethylene glycol with air in the presence of a silver or copper catalyst (the LaPorte process) or liquid-phase oxidation of acetaldehyde with nitric acid.
  - Please provide feedback on production data and/or information on data sources of glyoxal and glyoxylic acid, nationally and disaggregated by state for 1990-2020.
3. **Calcium Carbide Production** - Please provide information on availability of data on calcium carbide production or petroleum coke used in calcium carbide production, and on calcium carbide used in the production of acetylene used for welding applications to estimate emissions using IPCC methods for 1990-2020.
4. **Phosphoric Acid Production** - Please provide feedback on data sources and assumptions, including:
  - The use of regional production capacity from 2005 to 2011 to estimate regional production from 2005 to 2020.
  - The carbonate composition of phosphate rock and how it varies depending upon where the material is mined and over time.
  - The disposition of the organic carbon content of the phosphate rock and the assumption that it remains in the phosphoric acid product and is not released as CO<sub>2</sub>. This includes feedback on the assumption that all domestically produced phosphate rock is used in phosphoric acid production and it is used without first being calcined.

## Metal Production

5. **Ferroalloy Production** - Please provide feedback on data sources and assumptions, including:
  - The use of 2010 national production ratios for ferrosilicon 25-55% Si, ferrosilicon 56- 95% Si, silicon metals, and miscellaneous alloys 32-65% Si to determine the ratio of national ferroalloy production by type for 2011 through 2020.
  - Data and/or information on data sources on production of ferroalloys by state for 1990- 2020.
6. **Lead Production** – Please provide data and/or information on data sources on primary and secondary production of lead by state for 1990-2020.

### Other IPPU Categories

7. **ODS Substitutes** - The EPA seeks feedback on possible sources of hydrofluorocarbon (HFC) use that are not reflected, or whose use is modeled lower than actual, as evident from a comparison of the underlying model with data reported under EPA's GHGRP.
8. **Nitrous Oxide from Product Uses** - Please provide feedback or data and/or information on data sources on nitrous oxide production, market share of end uses, and the emission factors for each end use for 1990-2020, nationally and by state.

## Agriculture

### Requests for Expert Feedback for the 1990-2020 Agriculture Chapter

#### *General Questions:*

1. Provide your overall impressions of the clarity and transparency of the Agriculture chapter.
2. Provide feedback on the methodologies, assumptions and activity data used to estimate emissions for categories within the Agriculture chapter. In particular, provide feedback on sources of activity data for U.S. states or territories.

#### *Source Specific Questions:*

1. For the Manure Management source category, is the state of the industry current accurately described? Are there other technologies, practices, trends that we should consider?
2. Are the parameters and discussion of uncertainty within the Manure Management source category estimates adequately reflecting all uncertainties from this industry and the data EPA is currently using?
3. The Manure Management source category relies on national/regional livestock production and management data for calculating emissions estimates from USDA APHIS and NASS. Are there other/newer data sources that EPA should be aware of and consider in the calculating these emissions? Especially for:
  - Waste management system data, particularly seasonal changes in emissions from different WMS;
  - Maximum methane producing capacity;
  - Volatile solids and nitrogen excretion rates;
  - Measured emission estimates (by waste management system) to help refine estimates of methane conversion factors.
4. For the Enteric Fermentation source category, is the state of the industry current and accurately described? Are there other technologies, practices, trends that we should consider?
5. The Enteric Fermentation source category relies on national/regional livestock production, diet and management data for calculating emissions estimates. Are there other/newer data

sources or methods that EPA should be aware of and consider in the calculating these emissions? Especially for:

- Dry matter/gross energy intake;
  - Annual data for the DE,  $Y_m$ , and crude protein values of specific diet and feed components for foraging and feedlot animals;
  - Monthly beef births and beef cow lactation rates;
  - Weights and weight gains for beef and dairy cattle.
6. For the Enteric Fermentation source category and the Cattle Enteric Fermentation Model (CEFM), are the various regional designations of U.S. states (as presented in Annex 3.10) used for characterizing the diets of foraging cattle appropriate? The CEFM is used to estimate cattle CH<sub>4</sub> emissions from enteric fermentation, and incorporates information on livestock population, feeding practices, and production characteristics.

## Land Use, Land-Use Change, and Forestry (LULUCF)

### Requests for Expert Feedback for the 1990-2020 LULUCF Chapter

#### *General*

1. Provide your overall impressions of the clarity and transparency of the categories provided in the attached draft LULUCF chapter.
2. Provide any recommendations that EPA can consider to improve the completeness and/or accuracy of the attached draft LULUCF chapter.
3. Provide feedback on the methodologies and activity data used to estimate emissions for categories within the attached draft LULUCF chapter.

#### *Category Specific*

1. For the Yard Trimmings and Food Scraps category, is the state of the sector current and accurately described? Are there other technologies, practices, trends that we should consider?
2. For the Yard Trimmings and Food Scraps category, are there other data sources that EPA should be aware of and consider in the calculating these emissions? Especially for:
  - C storage, decay rates, etc. for yard trimmings and food scraps
  - Decay rates of food scraps, leaves, grass, and branches
  - National yard waste compositions
  - Precipitation range percentages for populations for the decay rate sensitivity analysis
3. For Forest Lands, new data for Alaska has been integrated and the analysis has been rerun and the methods for forest fires have been refined. Input on these improvements would be appreciated.
4. For Flooded Lands Remaining Flooded Lands and Lands Converted to Flooded Lands, are there other data sources that could improve the area estimates for the different types of flooded lands? These are both new categories this year so a review of the data and methods would be appreciated.



# Waste

## Requests for Expert Feedback for the 1990-2020 Waste Chapter

### *General*

1. Please provide your overall impressions of the clarity and transparency of the Waste chapter.
2. Please provide any recommendations that EPA can consider to improve the completeness and/or accuracy of the Waste chapter (see subsector specific questions below as well).

### *Wastewater Treatment and Discharge*

1. For **domestic wastewater** emissions, please provide input on:
  - a. National level data on the type of wastewater treatment systems in operation,
  - b. Whether the state of domestic wastewater treatment is current and accurately described,
  - c. National level data on the biogas generation and recovery operations,
  - d. Whether the estimate of BOD and N discharged in effluent should be estimated using limited data from ICIS-NPDES rather than average values of the percent of BOD or N removed by aerobic, anaerobic, and other treatment systems,
  - e. The revision of the non-consumed protein factor ( $F_{\text{NON-CON}}$ ) for centralized treatment to the default IPCC (2019) factor, and whether there are any sources to create a U.S.- specific factor,
  - f. Any additional sources for the N content of sludge, amount of sludge produced, and sludge disposal practices, and
  - g. Any additional sources for estimating the wastewater volume discharged to the type of aquatic environment for the time series.
2. For **industrial wastewater** emissions, please provide input on:
  - a. Any additional sources of wastewater outflow, BOD generation, N entering treatment, BOD discharged, or N discharged for industries included in the inventory,
  - b. National or state level production data for industries included in the inventory,
  - c. National level data on the type of wastewater treatment systems in operation for industries included in the inventory,
  - d. Whether the state of industrial wastewater treatment is current and accurately described,
  - e. National level data for biogas generation and recovery operations for industries included in the inventory, and
  - f. Any sources for estimating the wastewater volume discharged by type of aquatic environment for the time series.
3. Are there additional industries that are sources of methane or nitrous oxide emissions that should be included in the wastewater emission estimates? Are there available sources of national-level data for these industries (e.g., wastewater volume, treatment systems, wastewater discharge location information, production data, BOD production,

BOD or N removal, N entering treatment)? Are there available sources of state-level data for these industries?

4. Do you have suggestions for improving the discussion of our methodology? Is there any additional information that should be included to provide additional transparency? Are there any presentation changes that would help clarify methodologies or activity data used?

### **Landfills**

1. Based on comments received for the 1990-2019 Inventory we have updated the methodology used to develop the scale-up factor to use a time-based threshold on the waste in place. This methodology is presented in the “RTI 2021 Scale Up Factor Memo” provided. This methodological change results in recommended use of the 9% scale up factor for 2005 to 2016 and 11% for 2017 to 2020, which are the same factors used in the 1990-2019 Inventory. Please comment on the approach taken and selected time threshold. Please provide information on any portion of the approach that is unclear. The non-reporting database is available upon request.
2. New for the 1990-2020 Inventory is the inclusion of MSW landfill activity data in the chapter text tables. This includes MSW CH<sub>4</sub> generation, MSW CH<sub>4</sub> oxidized, and MSW CH<sub>4</sub> recovered. These values were not included in chapter tables for recent publication years because of the methodological change that occurs in 2005. We have developed a methodology to estimate these values for this publication year and would like feedback on methods and assumptions. In brief (see Methodology and Timeseries Consistency section and Annex 3.14 for more details):
  - MSW CH<sub>4</sub> Recovered is calculated for
    - 2005-2009: using estimates from the 4 recovery databases
    - 2010-2020: using reported HH recovery data + SUF of 9% and 11%
  - MSW CH<sub>4</sub> Oxidized is calculated for
    - 2005-2009: OX varies from 0.11 to 0.15 due to use of HH net emissions
    - 2010-2012: using a static average of 0.174
    - 2013-2020: using weighted average OX by RY, which varies between 0.174 in 2014 to 0.220 in 2020
  - MSW CH<sub>4</sub> Generated for 2010-2020 is calculated by solving for GCH<sub>4</sub> in this equation: Net emissions = (GCH<sub>4</sub> – R)\*(1-OX) for each year.

### **Composting**

1. Please comments on datasets available on industrial composting facilities located in the U.S. territories of Puerto Rico, Guam, U.S. Virgin Islands, Northern Mariana Islands, and American Samoa. We are aware of composting facilities in Puerto Rico. In order to accurately estimate GHG emissions from these facilities, data is needed on the first year of operation, approximate annual quantities processed or number of households serviced, and whether the amount of waste composted is consistent from year to year.

### **Anaerobic Digestion at Biogas Facilities**

1. Previously titled stand-alone anaerobic digestion, please comment on the clarity and transparency of the methodology used to develop the emission estimates. The methodology relies heavily on the EPA data collection survey of anaerobic digestion facilities for 2015 to 2018 (US EPA 2018, 2019, and 2021<sup>2</sup>). We are specifically interested in confirming the count of operational facilities per year and the accuracy of using the weighted average (versus the median) of the 2015 and 2016 survey data to estimate annual waste processed from 1990 to 2014.
2. Please comment on potential facility-specific data sources we could use to fill data gaps on the quantity of waste processed by stand-alone digesters for any and all years of the 1990 to 2020 time series.

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<sup>2</sup> EPA (2021). Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018): Survey Results. January 2021 EPA/903/S-21/001. Available online at < [https://www.epa.gov/sites/default/files/2021-02/documents/2021\\_final\\_ad\\_report\\_feb\\_2\\_with\\_links.pdf](https://www.epa.gov/sites/default/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf)>.

EPA (2019). Anaerobic Digestion Facilities Processing Food Waste in the United States in 2016: Survey Results. September 2019 EPA/903/S-19/001. Available at < [https://www.epa.gov/sites/production/files/2018-08/documents/ad\\_data\\_report\\_final\\_508\\_compliant\\_no\\_password.pdf](https://www.epa.gov/sites/production/files/2018-08/documents/ad_data_report_final_508_compliant_no_password.pdf)>.

EPA (2018). Anaerobic Digestion Facilities Processing Food Waste in the United States in 2015: Survey Results. May 2018 EPA/903/S-18/001. Available at < [https://www.epa.gov/sites/production/files/2019-09/documents/ad\\_data\\_report\\_v10\\_-\\_508\\_comp\\_v1.pdf](https://www.epa.gov/sites/production/files/2019-09/documents/ad_data_report_v10_-_508_comp_v1.pdf)>.

# **Appendix D: Supplemental Technical Memos to Expert Reviewers for Energy, IPPU, and Waste Sectors**

- 1) Updates Under Consideration for Active Coal Mine Fugitive CO<sub>2</sub> Emission Estimates
- 2) Proposed Methodological Refinements for Glass Production
- 3) Proposed Improvements to the Waste Incineration Data Analysis
- 4) Carbon Dioxide Transport, Injection, and Geologic Storage in the Inventory of U.S. Greenhouse Gas Emissions and Sinks

# Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates Under Consideration for Active Coal Mine Fugitive CO<sub>2</sub> Emission Estimates

This memo discusses updates under consideration for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) to include CO<sub>2</sub> fugitive emission estimates for active coal mining sources.

## Introduction

Fugitive CO<sub>2</sub> emission estimates for active coal mining are currently not included in the GHGI. EPA is considering adding these CO<sub>2</sub> estimates for coal mining to the GHGI, based on the methods recommended in the 2019 Refinement to the 2006 IPCC Guidelines.<sup>1</sup>

## Methodology

Methane and CO<sub>2</sub> are naturally occurring in coal seams and are collectively referred to as coal seam gas. These gases remain trapped in the coal seam until coal is mined (i.e., coal seam is exposed and fractured during mining operations). Fugitive CO<sub>2</sub> emissions occur during underground mining, surface coal mining, and post-mining activities. Methods and data to estimate fugitive CO<sub>2</sub> emissions from underground and surface coal mining are presented separately in the sections below. IPCC methods and data to estimate fugitive CO<sub>2</sub> emissions from post-mining activities (for both underground and surface coal mining) are currently not available.

The 2019 Refinement includes IPCC Tier 1, Tier 2, and Tier 3 methodologies for estimating fugitive CO<sub>2</sub> emissions from coal mining. The Tier 1 methodology estimates fugitive CO<sub>2</sub> emissions using default CO<sub>2</sub> emission factors (EFs) based on global averages. The Tier 2 methodology requires basin-level CO<sub>2</sub> EFs that could be developed using CO<sub>2</sub> measurement data and the Tier 3 methodology depends on mine-level measurement data to estimate CO<sub>2</sub> emissions.

## Underground Mining

EPA is proposing to use an IPCC Tier 1 method to estimate fugitive CO<sub>2</sub> emissions from underground coal mining. EPA is not aware of the availability of data necessary to implement the Tier 2 or Tier 3 methods.

The IPCC methodology uses the following overarching IPCC equation to estimate fugitive CO<sub>2</sub> emissions from underground coal mines:

IPCC 2019 Refinement	Vol 2, Chapter 4	Equation 4.1.2 (page 4.15)
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*Total CO<sub>2</sub> from Underground Mines*

$$\begin{aligned} &= \text{CO}_2 \text{ from underground mining} - \text{Amount of CO}_2 \text{ in gas recovered} \\ &+ \text{CO}_2 \text{ from methane flaring} \end{aligned}$$

<sup>1</sup> 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 2, Chapter 4, Section 4.1. Available online at: <https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol2.html>.

Fugitive CO<sub>2</sub> emissions from underground mining can be estimated using the IPCC equation below and an IPCC Tier 1 emission factor (EF).

IPCC 2019 Refinement	Vol 2, Chapter 4	Equation 4.1.3A (page 4.19)
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$$CO_2 \text{ from underground mining} = CO_2 \text{ Emission Factor} \times \text{Coal Production} \times \text{Conversion Factor}$$

The IPCC Tier 1 CO<sub>2</sub> EFs are based on annual coal production from underground mines and are presented in Table 1, below.

Table 1. CO<sub>2</sub> Emission Factors for Underground Mining.

Coal Production Type	CO <sub>2</sub> Emission Factor (m <sup>3</sup> /metric ton) <sup>a</sup>		
	Low EF	Average EF	High EF
Underground Mining	0.05	5.9	12.3

<sup>a</sup> Conversion factor of 1.84 X 10<sup>-6</sup> Gg/m<sup>3</sup> can be used to convert CO<sub>2</sub> from volume to mass.

The CO<sub>2</sub> EFs in Table 1 are based on global averages. The choice of low, average, and high EF values depends on the depth of coal seam for underground mines. The IPCC recommends using the average EF values unless there is country-specific evidence to support the use of low or high EF values. EPA is considering using the average CO<sub>2</sub> EF to estimate emissions from underground mining. The conversion factor (1.84 X 10<sup>-6</sup> Gg/m<sup>3</sup>) is the density of CO<sub>2</sub> and is used to convert emissions from volume to mass units.

The required activity data to estimate fugitive CO<sub>2</sub> emissions from underground coal mining are national-level annual coal production from underground mines. Time-series data (i.e., 1990-2019) are available from EIA's *Annual Coal Report* and are currently used in the GHGI for other sources.<sup>2</sup>

The Tier 1 EFs includes all the fugitive CO<sub>2</sub> likely to be emitted from underground coal mining. Therefore, the amount of CO<sub>2</sub> from coal seam gas recovered and utilized for energy is subtracted from underground mining estimates. Under IPCC methods, the CO<sub>2</sub> emissions from gas recovered and utilized for energy use (e.g., injected into a natural gas pipeline) are reported under other sectors of the GHGI (e.g., stationary combustion of fossil fuel or oil and natural gas systems) and not under the coal mining sector.

Estimating the fugitive CO<sub>2</sub> emissions that do not occur, as a result of recovered coal seam gas, requires knowing the CO<sub>2</sub> content in the recovered gas. The IPCC method for underground coal mining in the IPCC 2019 Refinement does not include emission factors for the CO<sub>2</sub> content of coal seam gas. However, a Tier 1 EF for fugitive CO<sub>2</sub> emissions from coal bed methane production is available in the IPCC2019

<sup>2</sup> Annual Coal Report, U.S. Energy Information Administration. Available online at: <https://www.eia.gov/coal/annual/>.

Refinement (19.57 metric tons CO<sub>2</sub>/million cubic meters of CBM produced).<sup>3</sup> EPA is proposing to use this emission factor for coal bed methane and apply it to the method for underground coal mining.

The amount of CO<sub>2</sub> to be deducted (i.e., CO<sub>2</sub> from recovered coal seam gas) from underground mining CO<sub>2</sub> estimates can be estimated using the following equation:

$$\text{Amount of CO}_2 \text{ from recovered gas} = \text{CO}_2 \text{EF} \times \text{Quantity of recovered gas}$$

Where,

CO<sub>2</sub> EF = 19.57 metric tons/million cubic meters gas.

National-level data on recovered coal seam gas delivered to a pipeline are available from the coal mining section of the GHGI for the entire time-series. The GHGI for 1990-2019 for coal mining indicates there are 12 mines that delivered recovered gas to a pipeline in 2019.

The method in the IPCC 2019 Refinement indicates that the combustion CO<sub>2</sub> emissions from gas recovered for non-energy uses (i.e., flaring, or catalytic oxidation) should be added to fugitive CO<sub>2</sub> emission estimates for underground coal mining. In effect, these emissions, though occurring through stationary combustion, are categorized as fugitive emissions for the purposes of the IPCC method.

CO<sub>2</sub> emissions from methane flaring can be estimated using the following IPCC equation (IPCC Equation 4.1.5):

IPCC 2019 Refinement	Vol 2, Chapter 4	Equation 4.1.5 (page 4.21)
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*CO<sub>2</sub> from flaring*

$$= 0.98 \times \text{Volume of methane flared} \times \text{Conversion Factor} \\ \times \text{Stoichiometric Mass Factor}$$

In the coal mining GHGI, there is only a single mine that reports catalytic oxidation of recovered methane.<sup>4</sup>

## Surface Mining

EPA is proposing to use an IPCC Tier 1 method to estimate fugitive CO<sub>2</sub> emissions from underground coal mining. EPA is not aware of the availability of data necessary to implement the Tier 2 or Tier 3 methods.

Fugitive CO<sub>2</sub> emissions from surface mining can be estimated using the IPCC equation below and an IPCC Tier 1 emission factor (EF).

IPCC 2019 Refinement	Vol 2, Chapter 4	Equation 4.1.7A (page 4.25)
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$$\text{CO}_2 \text{ emissions from surface mining} = \text{CO}_2 \text{ Emission Factor} \times \text{Coal Production} \times \\ \text{Conversion Factor}$$

<sup>3</sup> 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 2, Chapter 4, Section 4.2, Table 4.2.4 (G). Available online at: [https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2\\_Volume2/19R\\_V2\\_4\\_Ch04\\_Fugitive\\_Emissions.pdf](https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2_Volume2/19R_V2_4_Ch04_Fugitive_Emissions.pdf).

<sup>4</sup> Marshall County Mine (McElroy VAM project, WV).

The CO<sub>2</sub> EFs are based on annual coal production from surface mines and are presented in Table 2 below.

Table 2. CO<sub>2</sub> Emission Factors for Surface Mining.

Coal Production Type	CO <sub>2</sub> Emission Factor (m <sup>3</sup> /metric ton) <sup>a</sup>		
	Low EF	Average EF	High EF
Surface Mining	0.01	0.44	0.94

<sup>a</sup> Conversion factor of  $1.84 \times 10^{-6}$  Gg/m<sup>3</sup> can be used to convert CO<sub>2</sub> from volume to mass.

Similar to the underground EFs, the CO<sub>2</sub> EFs in Table 2 are based on global averages. The choice of low, average, and high EF values depends on the overburden depth for surface mines. IPCC recommends using the average EF value unless there is country-specific evidence to support the use of low or high EF values. EPA is proposing using the average CO<sub>2</sub> EF to estimate emissions from surface mining. The conversion factor ( $1.84 \times 10^{-6}$  Gg/m<sup>3</sup>) is the density of CO<sub>2</sub> and is used to convert emissions from volume to mass units.

The required activity data to estimate fugitive CO<sub>2</sub> emissions from surface mining is national-level annual coal production from surface mines. Time-series data (i.e., 1990-2019) are available from EIA's *Annual Coal Report* and are currently used in the GHGI for other sources.

## Preliminary National Estimates

Using IPCC Tier 1 average EFs for fugitive CO<sub>2</sub> emissions from coal mining and EIA's annual coal production data, EPA developed preliminary annual fugitive CO<sub>2</sub> emission estimates for 1990-2019. Table 3 presents time-series annual fugitive CO<sub>2</sub> emissions from underground and surface mining. Annual fugitive CO<sub>2</sub> emissions for 2019 are estimated to be 2,951 kilotons (or 2.95 MMT CO<sub>2</sub>e). In Table 3, flaring emissions indicate CO<sub>2</sub> emissions from flaring of mine gas for non-energy uses, and these emissions are added to the fugitive underground mining estimates. CO<sub>2</sub> emission estimates from gas recovered and utilized for energy uses (i.e., delivered to a pipeline) are subtracted from the fugitive underground mining estimates.

Estimates of fugitive CO<sub>2</sub> emissions from post-mining activities are not included in Table 3 due to unavailability of IPCC estimation methods and data.

Table 3. Preliminary National CO<sub>2</sub> Estimates for 1990-2019 (Kilotons).

Year	CO <sub>2</sub> from Underground Mining				CO <sub>2</sub> from Surface Mining	Total CO <sub>2</sub>
	Liberated	Flaring <sup>a</sup>	Recovered CO <sub>2</sub>	UG Sub-total		
1990	4,171	0	7.6	4,164	443	4,606
1991	4,002	0	8.0	3,994	431	4,425
1992	4,002	0	9.4	3,992	433	4,425
1993	3,457	0	12.4	3,445	437	3,881
1994	3,931	0	14.8	3,916	466	4,382
1995	3,902	0	16.9	3,885	468	4,353
1996	4,036	0	20.9	4,015	480	4,496
1997	4,143	0	15.8	4,127	492	4,619
1998	4,114	0	19.5	4,094	514	4,608



Year	CO <sub>2</sub> from Underground Mining				CO <sub>2</sub> from Surface Mining	Total CO <sub>2</sub>
	Liberated	Flaring <sup>a</sup>	Recovered CO <sub>2</sub>	UG Sub-total		
1999	3,859	0	17.3	3,841	520	4,362
2000	3,671	0	20.4	3,651	515	4,165
2001	3,749	0	22.6	3,726	547	4,273
2002	3,520	0	24.0	3,496	540	4,036
2003	3,474	0	21.0	3,453	527	3,981
2004	3,620	0	22.0	3,598	546	4,144
2005	3,630	0	20.3	3,610	560	4,170
2006	3,536	0	25.2	3,511	590	4,100
2007	3,465	0	20.8	3,444	583	4,027
2008	3,517	0	22.1	3,495	597	4,092
2009	3,270	0	22.5	3,248	544	3,791
2010	3,320	0	27.2	3,293	547	3,841
2011	3,404	0	24.3	3,379	550	3,929
2012	3,372	11.3	21.4	3,362	494	3,856
2013	3,365	25.4	20.7	3,370	471	3,841
2014	3,493	31.0	19.2	3,505	473	3,978
2015	3,022	28.4	18.5	3,032	432	3,464
2016	2,483	34.4	18.4	2,499	349	2,848
2017	2,690	28.7	19.8	2,699	368	3,067
2018	2,712	24.0	21.4	2,714	353	3,067
2019	2,633	13.5	17.9	2,629	322	2,951

<sup>a</sup> Combustion CO<sub>2</sub> emissions reported here as fugitive emissions, per IPCC 2019 Refinement.

## Requests for Feedback

EPA seeks technical expert feedback on the updates under consideration discussed in this memo and the questions below.

1. EPA is considering using the Tier 1 “average” CO<sub>2</sub> EF (Tables 1 and 2) for underground and surface mining. EPA seeks feedback on the representativeness of these EFs for use at the national level.
2. EPA is considering using the CO<sub>2</sub> EF from onshore coal bed methane (CBM) production for recovered coal seam gas. EPA seeks feedback on the applicability and representativeness of this EF. (Note that the quantity of CO<sub>2</sub> from recovered gas in 2019 is estimated to be slightly less than 18 kilotons, which is less than 1 percent of total fugitive CO<sub>2</sub> emissions from coal mining.)
3. EPA is seeking information about data sources that would facilitate the use of Tier 2 methods, such as basin-specific CO<sub>2</sub> measurement data.

# Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Proposed Methodological Refinements for Glass Production

## 1 Background

EPA has researched and is proposing methodological refinements to the Glass Production source category of the U.S. Greenhouse Gas (GHG) Inventory based on identifying more recent and relevant activity data sources for total carbonates used in glass production. EPA conducted analyses during the 1990 to 2020 Inventory cycle to compare these data sources. This memorandum outlines these proposed methodological improvements, activity data sources, and analysis of , including preliminary national estimates reflect improvements.

## 2 Current National *Inventory* Methodology

Currently, the total quantity of each raw carbonate used in glass production (i.e., limestone, dolomite, and soda ash) is based on survey results from USGS.

Carbon dioxide emissions were calculated based on the *2006 IPCC Guidelines* Tier 3 method by multiplying the quantity of input carbonates (limestone, dolomite, and soda ash) by the carbonate-based emission factor (in metric tons CO<sub>2</sub>/metric ton carbonate): limestone, 0.43971; dolomite, 0.47732; and soda ash, 0.41492.

In 1991, the U.S. Bureau of Mines, now known as the USGS, began compiling production and end use information through surveys of crushed stone manufacturers. Each year, limestone and dolomite make up approximately 70% of the total crushed stone manufactured in the United States (USGS 1995 through 2016a). Crushed stone manufacturers provided different levels of detail in the survey responses, so information was divided into three categories: (1) production by end-use, as reported by manufacturers (i.e., “specified” production); (2) production reported by manufacturers without end-uses specified (i.e., “unspecified-reported” production); and (3) estimated additional production by manufacturers who did not respond to the survey (i.e., “unspecified-estimated” production).

The “specified” production portion of the report provides limestone and dolomite consumption for glass manufacturing. Large quantities of limestone and dolomite consumption are reported under the categories “unspecified–reported” and “unspecified–estimated” as well, and a portion of this consumption is believed to be limestone or dolomite used for glass manufacturing. The quantities listed under both “unspecified” categories were allocated to glass manufacturing according to the percentage of “specified” limestone or dolomite consumed for glass manufacturing end-use for that year.<sup>1</sup>

During 1990 and 1992, the U.S. Bureau of Mines did not conduct a detailed survey of limestone and dolomite consumption by end-use. Therefore, data on consumption by end-use for 1990 was estimated by applying the 1991 ratios of total limestone and dolomite consumption by end use to total 1990 limestone and dolomite consumption values. Similarly, the 1992 consumption figures were

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<sup>1</sup> This approach was recommended by USGS.

approximated by applying an average of the 1991 and 1993 ratios of total limestone and dolomite consumption by end-use to the 1992 total limestone and dolomite consumption values.

For 1990 through 1993, consumption data of limestone and dolomite used for glass manufacturing were obtained from the U.S. Bureau of Mines (1991 and 1993a), For 1994 through 2018, consumption data of limestone and dolomite used for glass manufacturing were obtained from the *USGS Minerals Yearbook: Crushed Stone Annual Report* (1995 through 2016a), and 2018 preliminary data from the USGS Crushed Stone Commodity Expert (Willett 2020a). The total limestone and dolomite used for glass manufacturing was determined in the same manner as described for 1991 above. Consumption data for limestone and dolomite used for glass manufacturing typically lagged by 2 years (i.e., 2019 values were not available at the time of publication for the 1990-2019 national Inventory, so 2018 values were used as proxy).

Each year the USGS withholds data on certain limestone and dolomite end-uses due to confidentiality agreements regarding company proprietary data. For the purposes of this analysis, emissive end-uses that contained withheld data were estimated using one of the following techniques: (1) the value for all the withheld data points for limestone or dolomite use was distributed evenly to all withheld end-uses; or (2) the average percent of total limestone or dolomite for the withheld end-use in the preceding and succeeding years.

For 1990 through 2019, consumption data for soda ash used for glass manufacturing were obtained from the U.S. Bureau of Mines (1991 and 1993a), the *USGS Minerals Yearbook: Soda Ash Annual Report* (1995 through 2015b) (USGS 1995 through 2015b), and *USGS Mineral Industry Surveys for Soda Ash* in April 2020 (USGS 2020).

### 3 Proposed National *Inventory* Methodological Improvements

Proposed improvements for Glass Production emissions estimates include use of total amounts of each carbonate used in glass production from the U.S. EPA Greenhouse Gas Reporting Program (GHGRP) as activity data, which would replace the activity data from U.S. Geological Survey (USGS), and on the addition of data on the average carbonate-based mineral mass fraction, which would improve the accuracy of emissions estimates. This GHGRP dataset is more complete than USGS data and accurate because of the GHGRP verification process but is known to be incomplete due to GHGRP's reporting threshold, described in section 3.1 below. Carbon dioxide emissions under the new methodology continue to be calculated based on the *2006 IPCC Guidelines* Tier 3 method by multiplying the quantity of input carbonates (i.e., limestone, dolomite, and soda ash) by the IPCC default carbonate-based emission factor (in metric tons CO<sub>2</sub>/metric ton carbonate), which are consistent with the current methodology (i.e., limestone, 0.43971; dolomite, 0.47732; and soda ash, 0.41492), and by the average carbonate-based mineral mass fraction for each year averaged from 2010 to 2020.

To account for time series consistency, proposed improvements incorporate the use of the Federal Reserve Industrial Production Index for glass production in the United States as a surrogate for the quantities of carbonates used in glass production for 1990 to 2009.

#### 3.1 Proposed Methodology Using GHGRP Activity Data for 2010 through 2020

The proposed methodology for estimating CO<sub>2</sub> emissions from glass production for years 2010 through 2020 uses new activity data on the quantities of limestone, dolomite, and soda ash used for glass production reported to the U.S. EPA Greenhouse Gas Reporting Program (GHGRP). GHGRP collects data

from glass production facilities with greenhouse gas emissions greater than 25,000 metric tons CO<sub>2</sub>e. The reporting threshold is used to exclude artisanal glass operations that are expected to have much lower greenhouse gas emissions than the threshold. These smaller facilities have not been accounted for yet for this portion of the time series.<sup>2</sup>

Facilities report the total quantity of each type of carbonate (e.g., limestone, dolomite, soda ash) used in glass production each year to GHGRP, with data collection starting in 2010 (EPA 2021). The specific data element is listed at 98.146 (b)(2): “Annual quantity of each carbonate-based raw material charged (tons) to all furnaces combined.”

Using the total quantities for 2010 through 2020, EPA calculated the metric tons of emissions resulting from glass production by multiplying the quantity of input carbonates (i.e., limestone, dolomite, and soda ash) by the same IPCC default carbonate-based emission factor used in the current methodology (in metric tons CO<sub>2</sub>/metric ton carbonate): limestone, 0.43971; dolomite, 0.47732; and soda ash, 0.41492 and by the average carbonate-based mineral mass fraction for each year from 2010 to 2020.

The current methodology assumed that limestone contained 100 percent CaCO<sub>3</sub>; dolomite contained 100 percent CaMg(CO<sub>3</sub>)<sub>2</sub>; and soda ash contained 100 percent Na<sub>2</sub>CO<sub>3</sub>. The average carbonate-based mineral mass fractions from the GHGRP, averaged across 2010 through 2020, indicate that the limestone used in glass production contained 98.6 percent calcium carbonate (CaCO<sub>3</sub>); dolomite contained 98.5 percent calcium magnesium carbonate (CaMg(CO<sub>3</sub>)<sub>2</sub>); and soda ash contained 99.2 percent sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>). The average carbonate-based mineral mass fraction data element is listed as part of 98.146 (b)(5): “carbonate-based mineral mass fraction for each carbonate-based raw material charged to a continuous glass melting furnace.”

### 3.2 Time Series Considerations (i.e., for 1990 through 2009)

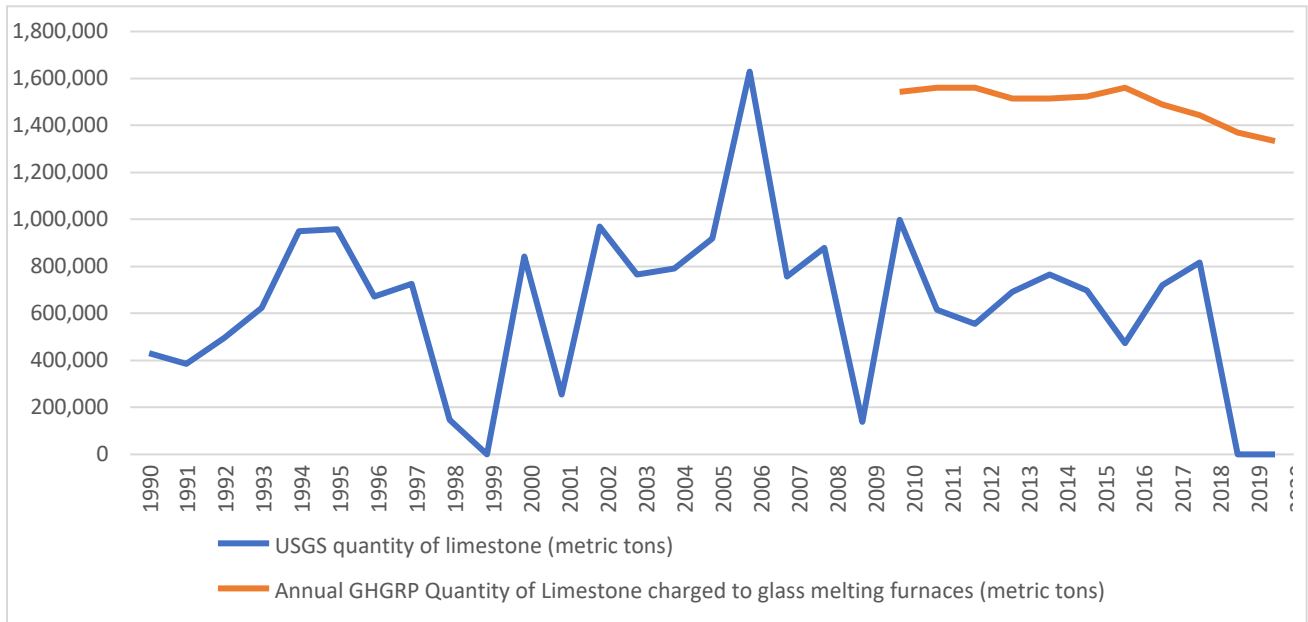
Data from GHGRP on the quantity of each type of carbonate used in glass production is not available for 1990 through 2009. To address this data gap, analysis comparing the USGS and GHGRP datasets were completed. Based on a comparison of the USGS data to the GHGRP data for years 2010 to 2020, it appears that the USGS dataset for 1990 through 2009 underestimated the amount of dolomite and limestone used in glass production and may have overestimated the amount of soda ash used in glass production.

See Figures 1, 2, and 3 for the comparison of limestone, dolomite, and soda ash used in glass production, respectively.

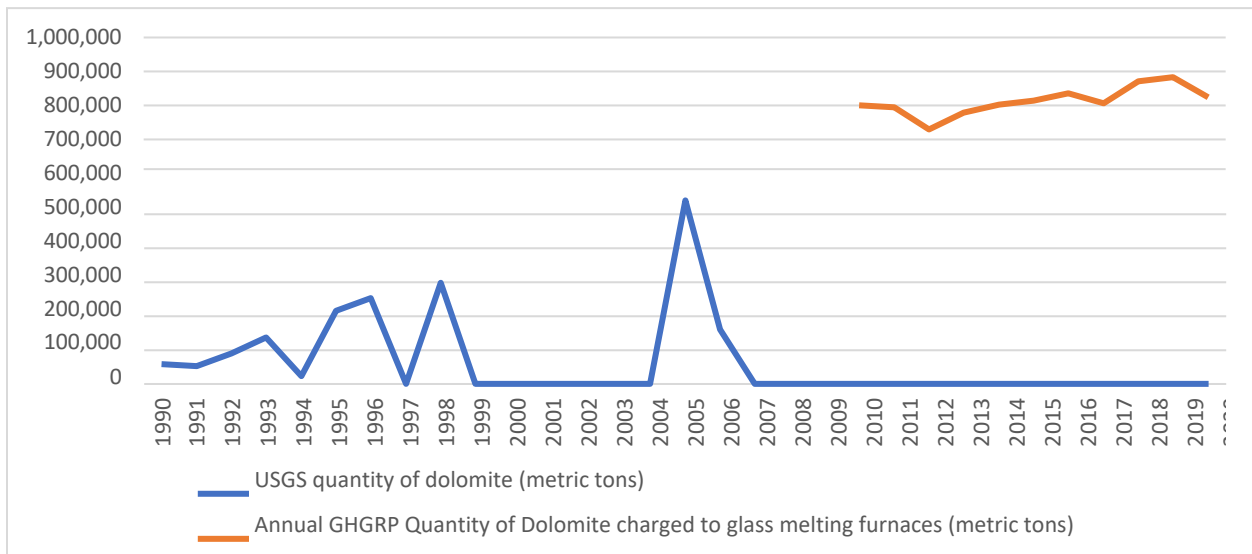
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<sup>2</sup> Prior to promulgation of Part 98 and the GHGRP, the EPA estimated that the entire glass industry in the United States consisted of 374 facilities emitting approximately 1.6 million metric tons CO<sub>2</sub>e in process emissions from glass production (EPA 2009). By setting the reporting threshold at 25,000 metric tons CO<sub>2</sub>e, facility coverage was estimated at 14.7% (55 facilities) and emissions coverage was estimated at 50.7% (0.84 million metric tons CO<sub>2</sub>e). This assessment is available in the *Technical Support Document for the Glass Manufacturing Sector: Proposed Rule for Mandatory Reporting of Greenhouse Gases*: <https://www.epa.gov/ghgreporting/subpart-n-technical-support-document>. During 2010 which was the first reported year however, a total of 110 glass production facilities reported total process emissions of 2.0 million metric tons CO<sub>2</sub>e. Because EPA received data from more facilities than expected and received total emissions higher than was expected for all glass production facilities in the United States, it is difficult to estimate the completeness of the GHGRP dataset.

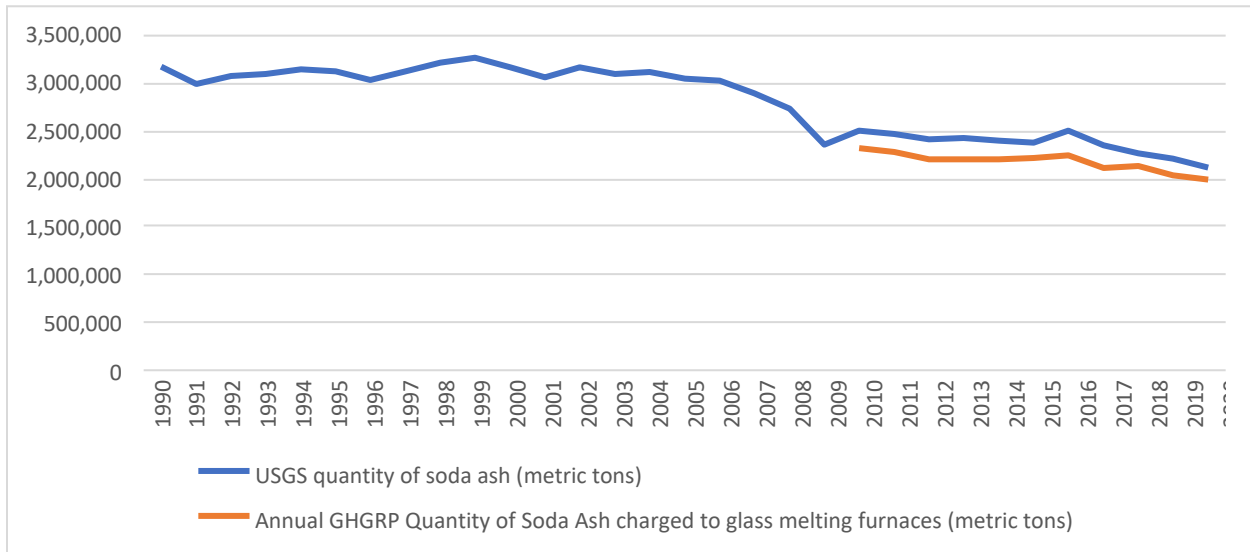
**Figure 1. Comparison of the amount of limestone used for glass production based on USGS data and the amount of limestone used for glass production based on GHGRP data**



**Figure 2. Comparison of the amount of dolomite used for glass production based on USGS data and the amount of dolomite used for glass production based on GHGRP data**



**Figure 3. Comparison of the amount of soda ash used for glass production based on USGS data and the amount of soda ash used for glass production based on GHGRP data**



The average amount of limestone used in glass production for 2010 through 2020 based on USGS data was 19.1 percent of total emissions from glass production, compared to an average of 33.5 percent of total emissions based on GHGRP data. The average amount of dolomite used in glass production based on USGS data was zero for all years from 2010 through 2020, whereas GHGRP data showed dolomite consumption accounting for an average of 19.8 percent of total emissions. The average amount of soda ash used in glass production based on USGS data was 80.9 percent of total emissions from glass production for 2010 through 2020; GHGRP data showed that soda ash consumption accounted for an average of 46.7 percent of total emissions. See Table 1 below for these values. The USGS and GHGRP datasets also showed an inconsistent overlap for 2010 to 2020.

**Table 1. Average percent contribution of each carbonate to total annual emissions from glass production for 2010-2020**

Carbonate	Average percent contribution to total annual emissions for 2010 through 2020	
	Based on USGS data	Based on GHGRP data
Limestone	19.1%	33.5%
Dolomite	0%	19.8%
Soda Ash	80.9%	46.7%

Because of the differences in USGS and GHGRP datasets for 2010 to 2020 and to refine methods and ensure methodological consistency over time, total emissions from 1990 to 2009 were calculated using the Federal Reserve Industrial Production Index for the United States as a surrogate for the quantities of carbonates used in glass production. The production index measures real output expressed as a percentage of real output in a base year, which is currently 2017 (Federal Reserve 2021).

Since January 1971, the Federal Reserve has released the monthly glass production index for NAICS code 3272 (Glass and Glass Product Manufacturing) as part of release G.17, “Industrial Production and

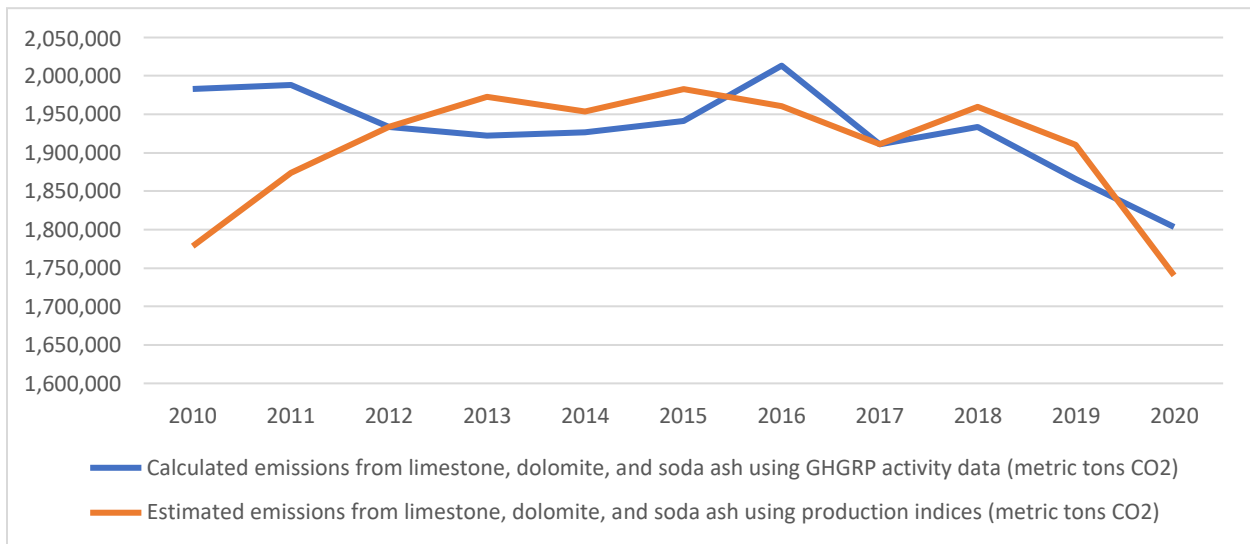
Capacity Utilization” (Federal Reserve 2021). The monthly index values for each year were averaged to calculate an average annual glass production index value. Total annual emissions were calculated by taking a ratio of the average annual glass production index for each year, with a base year of 2017, and the calculated 2017 emissions based on GHGRP data (Equation 1).

$$Estimated\ emissions_i = \frac{Calculated\ emissions_{2017}}{Production\ index_{2017}} * Production\ Index_i \quad \text{Equation 1}$$

- Estimated emissions<sub>i</sub> = Estimated emissions for year i (metric tons CO<sub>2</sub>)
- Calculated emissions<sub>2017</sub> = Total calculated emissions using GHGRP activity data from glass production in 2017 (metric tons CO<sub>2</sub>)
- Production Index<sub>i</sub> = Annual average glass production index from the Federal Reserve for year i
- i = Year from 1990-2009

For quality control of the proposed methodology, the calculated emissions using GHGRP data and the estimated emissions using the Federal Reserve glass production index (base year = 2017) were compared for years 2010 to 2020 when both datasets overlap, shown in Figure 4. The values differ by as much as 10 percent in the year 2010, but the average difference is about 1 percent from 2010 to 2020. This comparison shows that these two methods are closely correlated.

**Figure 4. Comparison of emissions calculated using GHGRP activity data and the estimated emissions using the Federal Reserve glass production index, for years 2010 to 2020**



Total annual emissions were disaggregated into emissions from limestone, dolomite, and soda ash using the average percent contribution of each carbonate to total emissions for 2010 through 2020, based on GHGRP data: limestone, 33.5 percent; dolomite, 19.8 percent; and soda ash, 46.7 percent.

## 4 Preliminary Emissions Estimates

Overall, the proposed methodological refinements led to an increase in emissions by an average of 40 percent across the time series from the Glass Production source category, compared to the current methodology (see Table 2). The observed increase in emissions is primarily due to differences in the quantities of carbonates used to produce glass. Emissions based on USGS data are calculated based on many assumptions (see Section 2.1), while the GHGRP values are supplied directly from individual glass production facilities in the United States with greenhouse gas emissions greater than 25,000 metric tons CO<sub>2</sub>e.

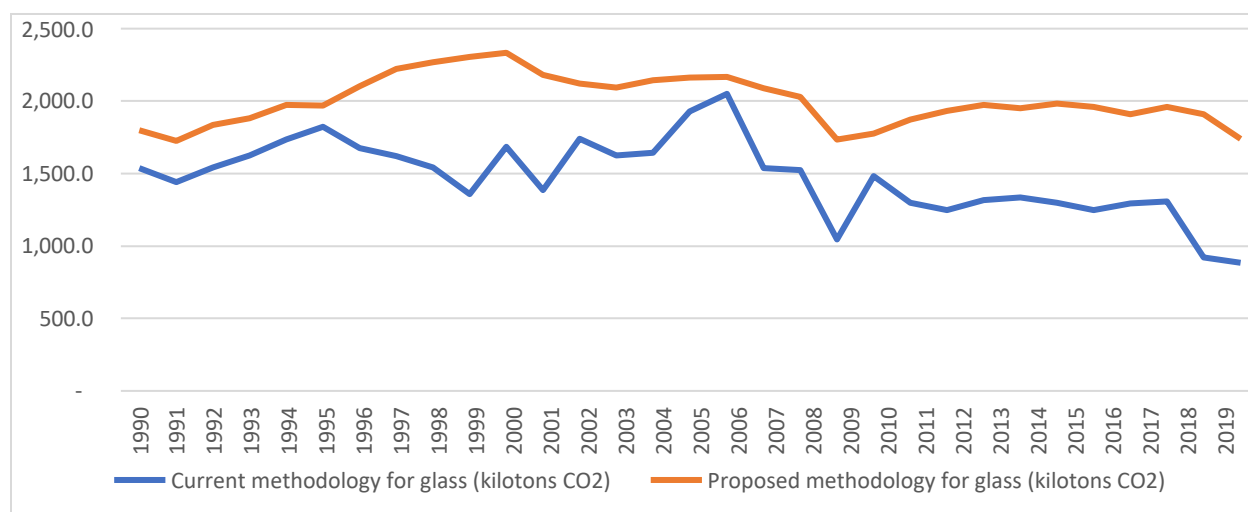
**Table 2. Preliminary emissions estimates based on USGS and GHGRP activity data (kt CO<sub>2</sub>e)**

Activity Data Source	1990	2005	2016	2017	2018*
USGS (current)	1,535	1,928	1,249	1,296	1,306
GHGRP (proposed)	1,802	2,161	1,960	1,911	1,959
% Difference	17%	12%	57%	47%	50%

\* 2018 value is shown here because due to data availability, 2019 values in the 1990-2019 Inventory used some 2018 values as proxies.

Figure 5, below, shows the differences in emissions for each year from 1990 through 2020, comparing the current/previous methodology using USGS data for years 1990 to 2020 and the proposed new methodology using GHGRP data for years 2010 to 2020 and the Federal Reserve Industrial Production Index for glass production.

**Figure 5. Comparison of CO<sub>2</sub> emissions from glass production using the current methodology and the proposed methodology**



## 5 Planned Improvements

Within the next two the Inventory cycles (i.e., with publication of April 2024 inventory covering 1990-2022), EPA anticipates updating this proposed methodology to include emissions from barium carbonate, potassium carbonate, lithium carbonate, and strontium carbonate, assuming the mass fraction of these four carbonates meets GHGRP confidential business information (CBI) screening



criteria. The quantities and mass fraction of these four carbonates are reported to the GHGRP for years 2010 to 2020. The quantities are estimated to be much less than limestone, dolomite, and soda ash. USGS does not collect data on the quantities of these carbonates used in glass production.

Additionally, some glass producing facilities in the United States do not report to GHGRP because they fall below the reporting threshold. EPA will initiate research on the availability of data to better assess the completeness of emission estimates from glass production and assess how to refine the methodology to ensure complete national coverage of this category. Research will include reassessing previous assessments of GHGRP industry coverage using the reporting threshold of 25,000 metric tons CO<sub>2</sub>e encompassing 50.7% of total emissions.<sup>3</sup> Another area of closer analysis to further refine this methodology will be to assess use of USGS data on soda ash used in glass production, which was consistently higher than the GHGRP data and was the only carbonate that had a relatively consistent overlap with GHGRP data for 2010 through 2020 (see Figure 3).

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<sup>3</sup> For the previous assessment, see *Technical Support Document for the Glass Manufacturing Sector: Proposed Rule for Mandatory Reporting of Greenhouse Gases*, available here: <https://www.epa.gov/ghgreporting/subpart-n-technical-support-document>.

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Willett (2020a) Personal communication, Jason Willett, U.S. Geological Survey and Amanda Chiu, U.S. Environmental Protection Agency. November 16, 2020.

# Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Proposed Improvements to the Waste Incineration Data Analysis

## 1 Introduction

EPA has researched and is proposing potential improvements to the Incineration of Waste source category of the U.S. Greenhouse Gas (GHG) Inventory by identifying more recent and relevant activity data sources for total waste incinerated and associated CO<sub>2</sub> emissions. EPA conducted analyses during the 1990-2020 Inventory cycle to implement a new methodology for this source category. This memorandum outlines these proposed improvements, data sources, and analysis.

## 2 Current Method and Data Sources

For additional information on the current waste incineration methodology, please refer to the EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2019 (EPA 2021). The following sections provides a brief overview of the approach to estimating emissions for the waste incineration source category by gas.

### 2.1 CO<sub>2</sub> Emissions Methodology

In the current methodology, CO<sub>2</sub> emissions from the incineration of waste are calculated separately by material for plastics, synthetic rubber, synthetic fibers in municipal solid waste (MSW), and scrap tires. Data on the quantity of product disposed from all materials except scrap tire are from Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures (EPA 2000 - 2003, 2005 - 2014); Advancing Sustainable Materials Management: Facts and Figures: Assessing Trends in Material Generation, Recycling and Disposal in the United States (EPA 2015; EPA 2016; EPA 2018a; EPA 2019); and detailed unpublished backup data for some years not shown in the reports (Schneider 2007). For 2012 through 2019 data on total waste incinerated were assumed to equal the 2011 value from Shin (2014).

The amount of each MSW incinerated material (obtained from the EPA data and BioCycle incineration percent) is multiplied by its respective carbon content to calculate the total amount of carbon emitted. The carbon content of the product is based on the specific material properties. Information about scrap tire composition and the amount combusted were obtained from the Rubber Manufacturers' Association (RMA 2018).

### 2.2 Non-CO<sub>2</sub> Emissions Methodology

CH<sub>4</sub> and N<sub>2</sub>O emissions are a function of total waste incinerated in each year. The emission factors for CH<sub>4</sub> and N<sub>2</sub>O emissions per quantity of MSW combusted are default emission factors for the model continuously-fed stoker unit MSW incineration technology type and were taken from IPCC (2006). Data on waste disposed (excluding tires) and waste incinerated come from BioCycle's State of Garbage in America (van Haaren et al. 2010) (hereinafter referred to as BioCycle data) and Shin (2014). These sources are used for years 1990 through 2011, i.e., when the data were last updated. For time series estimates after 2011, data have been proxied using the 2011 disposal and incineration tonnages from Shin (2014).

## 3 Proposed Improvements

Proposed improvements for the 1990 to 2020 Inventory Waste Incineration estimates focus on two specific areas:

- (1) implementation of new data sources for MSW combusted values (i.e., tonnage) forestimating CO<sub>2</sub> and non-CO<sub>2</sub> (i.e., CH<sub>4</sub>, N<sub>2</sub>O) emissions and related time series considerations
- (2) updating the methodology by which CO<sub>2</sub> emissions are determined using one emission factor (kg CO<sub>2</sub> per short ton) for waste incinerated as opposed to individual waste components

### 3.1 MSW Combustion Tonnage

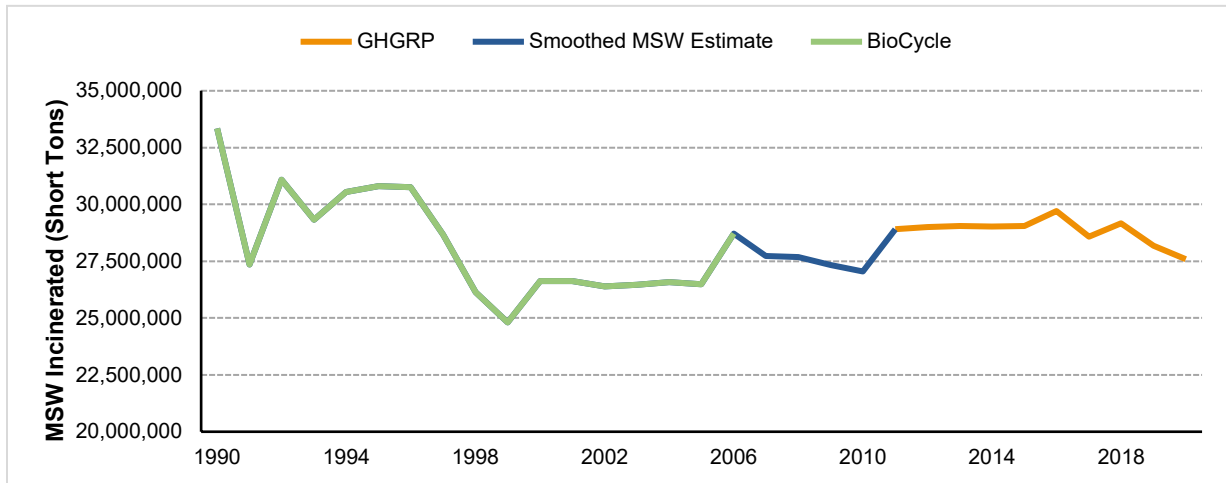
In constructing the new methodology for this year, EPA incorporated MSW incineration tonnage data from BioCycle, EPA Facts and Figures Reports, Energy Recovery Council (ERC) information, the EPA Greenhouse Gas Reporting Program (GHGRP) and the U.S. Energy Information Administration (EIA) to update the amount of waste incinerated. Data from BioCycle, EPA Facts and Figures, and EIA starts in 1990, while ERC data dates to 2001. EPA's Greenhouse Gas Reporting Program (GHGRP) collects data from facilities on methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions by fuel type. From these reported emissions for MSW fuel, EPA back-calculated the tonnage of waste incinerated using GHGRP default emission factors for CH<sub>4</sub> and N<sub>2</sub>O for 2011 through 2020.

EPA determined the MSW incineration tonnages based on data availability and accuracy throughout the time series.

- 1990-2006: MSW incineration tonnages are from Biocycle incineration data. Tire incineration data from RMA are removed to arrive at MSW incinerated without tires.
- 2006-2010: MSW incineration tonnages are an average of Biocycle (with RMA tire data tonnage removed), U.S. EPA Facts and Figures, EIA, and Energy Recovery Council data (with RMA tire data tonnage removed).
- 2011-2020: MSW incineration tonnages are from GHGRP data.

The proposed MSW incineration estimates are included in Figure 1.

Figure 1: MSW Incinerated Estimates (without tires), 1990-2020



Note: "Smoothed MSW Estimate" is an average of the following four sources: BioCycle, ERC, EIA, and EPA Facts and Figures

### 3.2 Use of GHGRP for CO<sub>2</sub> Emission Factor

EPA derived a fossil CO<sub>2</sub> emission factor using reported fossil CO<sub>2</sub> emissions from GHGRP FLIGHT data for facilities characterized as "MSW combustors" divided by the derived MSW incinerated tonnage from the CH<sub>4</sub> and N<sub>2</sub>O emissions data for years 2011 through 2020 for those same facilities. Note the MSW tonnage calculated for facilities characterized as MSW combustors is smaller than the total MSW tonnage back calculated from emissions by fuel type data. This indicates MSW could be co-fired at facilities whose main purpose is not waste combustion alone. For earlier years, the CO<sub>2</sub> emission factor was proxied using an average of the CO<sub>2</sub> emission factors from years 2011 through 2020. Table 1 shows the derived fossil CO<sub>2</sub> emission factors across the time series.

Table 1: Calculated Fossil CO<sub>2</sub> Content per Ton Waste Incinerated (Kg CO<sub>2</sub>/Short Ton Incinerated)

	1990*	2005*	2016	2017	2018	2019	2020
CO <sub>2</sub> Emission Factor	367	367	381	360	361	363	377

\* Average of emission factor from 2011 through 2020.

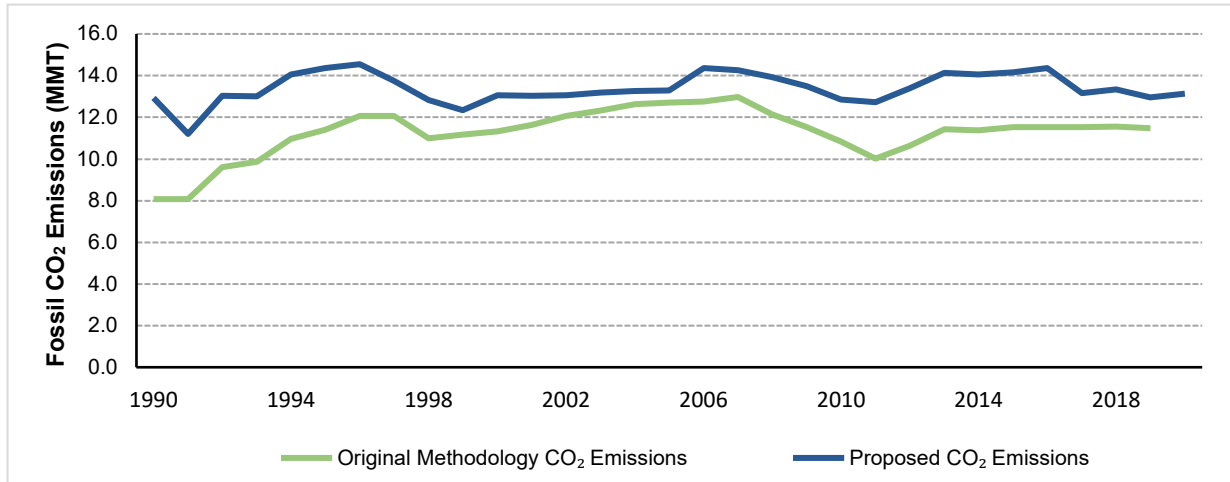
## 4 Preliminary National GHG Emissions Estimates

### 4.1 Preliminary National Carbon Dioxide Emissions

EPA calculated CO<sub>2</sub> emissions from non-tire MSW using the fossil CO<sub>2</sub> emission factor shown in Table 1 and the proposed total MSW combustion tonnage values described above and shown in Figure 1. EPA quantified tire emissions using tire incineration tonnages from RMA and corresponding carbon contents, consistent with the previous methodology. The resulting CO<sub>2</sub> emissions compared to the old methodology are shown in Figure 2.1

<sup>1</sup> 2020 data not included for the prior methodology.

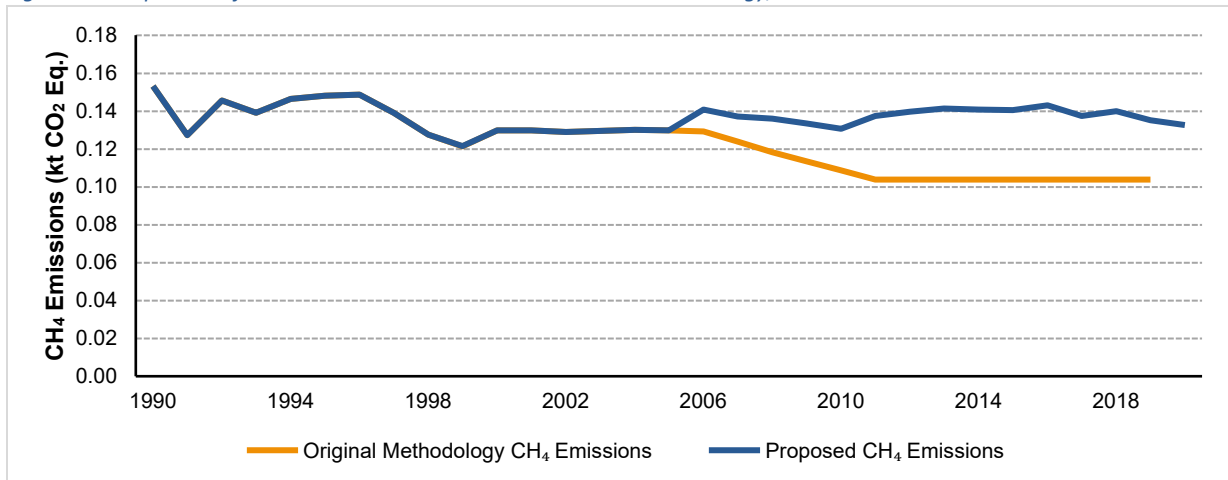
Figure 2: Comparison of CO<sub>2</sub> Emissions Under Old and New Methodology (including tires), 1990-2020



#### 4.2 Preliminary National Non-CO<sub>2</sub> Emissions

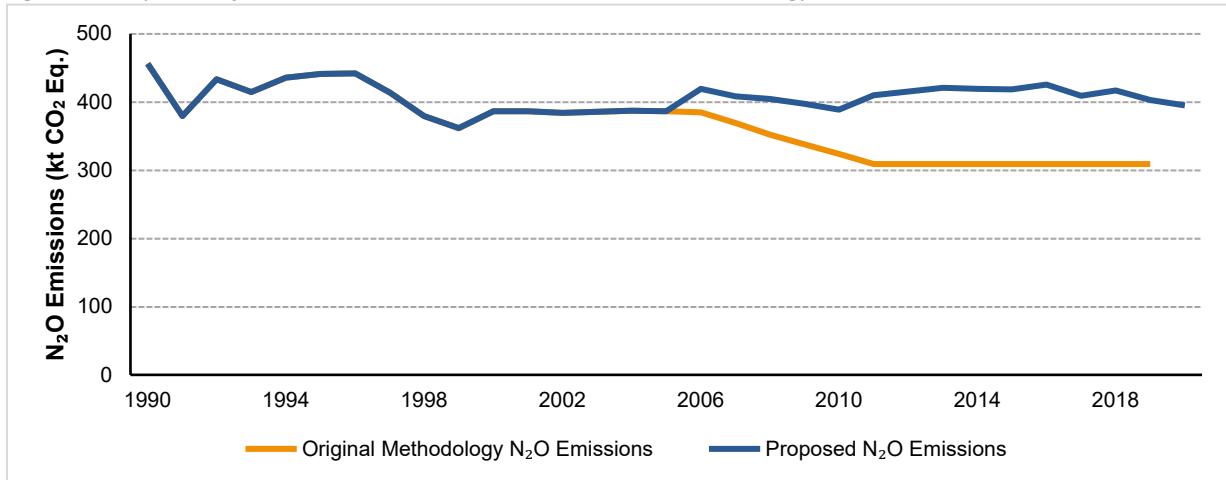
EPA applied the default IPCC emission factors for CH<sub>4</sub> and N<sub>2</sub>O to the new MSW tonnage estimates, including tire incineration data, to develop the non-CO<sub>2</sub> emissions. The resulting emissions changed as a result of the revised activity data of MSW incineration starting in 2006. A comparison of the emissions under the old and new methodology for methane and nitrous oxide can be seen in Figure 3 and Figure 4, respectively.<sup>2</sup>

Figure 3: Comparison of Methane Emissions Under Old and New Methodology, 1990-2020



<sup>2</sup> 2020 data not included for the prior methodology.

Figure 4: Comparison of Nitrous Oxide Emissions Under Old and New Methodology, 1990-2020



## 5 Impacts of Proposed Improvements on Emissions Estimates

Overall, the proposed changes in data sources and methodology will lead to an increase in 2019 emissions of 13% relative to the previous methodology and an average annual increase of 20% over the time series. Non-CO<sub>2</sub> emissions in 2019 of both CH<sub>4</sub> and N<sub>2</sub>O are 30% higher than the estimates using the prior methodology. The observed change in emissions is primarily due to the difference in MSW tonnages starting in 2010 and the revision of the CO<sub>2</sub> emission factors across the time series.

## 6 Charge Questions

EPA is requesting comment on the approach to use EPA’s GHGRP data for MSW combustors to derive an aggregate fossil CO<sub>2</sub> emission factor starting in 2011 for all waste incinerated (excluding tires).

EPA is requesting comment on the decision to apply the derived CO<sub>2</sub> emission factor to the total amount of MSW determined from GHGRP for 2011-2020 from back calculating the fuel emissions data.

Further, EPA is requesting comment on the decision to use a combination of MSW incineration tonnage data from several different sources across the time series.

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# Carbon Dioxide Transport, Injection, and Geologic Storage in the Inventory of U.S. Greenhouse Gas Emissions and Sinks

This memo discusses the current treatment of Carbon Dioxide Transport, Injection, and Geologic Storage in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019 (referred to as the “Inventory”) as defined by the Intergovernmental Panel on Climate Change (IPCC). It also identifies information and seeks feedback on approaches that EPA could consider using to improve how this subject is characterized in the Inventory.<sup>1</sup> This includes the use of data collected under EPA’s Greenhouse Gas Reporting Program (GHGRP) on geologic sequestration of carbon dioxide (CO<sub>2</sub>) and information on CO<sub>2</sub> transport and injection emissions.

## 1 Background and Current Inventory Methodology

Storage of captured CO<sub>2</sub> in geologic formations (such as deep saline formations, oil and gas reservoirs, and unmineable coal seams) is referred to as geologic sequestration. Geologic sequestration can also be achieved through enhanced oil and gas recovery (EOR), which involves the injection of CO<sub>2</sub> to extract additional oil and gas from underground reservoirs. Carbon capture and sequestration (CCS) refers to the capture and compression of CO<sub>2</sub> from power and industrial processes, transport of the captured CO<sub>2</sub> (typically in pipelines), and geologic sequestration.

CCS data are currently reflected in the Inventory in the following ways:

- CO<sub>2</sub> that is used in non-EOR industrial and commercial applications (e.g., food processing, chemical production) is assumed to be emitted to the atmosphere during its industrial use. These emissions are discussed in the Carbon Dioxide Consumption section (Inventory section 4.15 found here: [Chapter 4](#)).
- CO<sub>2</sub> used in EOR operations is assumed to be sequestered permanently, with the exception of CO<sub>2</sub> emitted through equipment in the process of natural gas and petroleum production (Inventory sections 3.5 and 3.6). As noted in the 2006 IPCC Guidelines, “At the Tier 1 or 2 methodology levels [EOR CO<sub>2</sub> is] indistinguishable from fugitive greenhouse gas emissions by the associated oil and gas activities.” In the Inventory estimates for oil and gas fugitive emissions, the Tier 2 emission factors for CO<sub>2</sub> include any CO<sub>2</sub> that was originally injected and is emitted along with other gas from leak, venting, and flaring pathways. Measurement data used to develop those factors does not distinguish between CO<sub>2</sub> from EOR and other CO<sub>2</sub> occurring in the produced natural gas.
- For industrial processes that capture CO<sub>2</sub> it is generally the case that the captured CO<sub>2</sub> is not subtracted or netted out of the emissions from that process with a few exceptions. Capture associated with natural gas process is discussed below and for situations where the captured CO<sub>2</sub> is accounted elsewhere in the Inventory it is netted out of the process. For example, the concentrated CO<sub>2</sub> that is captured during the ammonia production process and used to produce urea is not attributed as an emission from ammonia production. Instead, this captured CO<sub>2</sub> is attributed to the urea consumption or urea application source category in the Agriculture sector

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<sup>1</sup>This memo and its request for feedback is related solely to the reporting of national GHG emissions and sinks to the United Nations Framework Convention on Climate Change through the Inventory and has no impact on regulatory requirements related to the transport, injection and geologic storage of CO<sub>2</sub>.

(under the assumption that the carbon stored in the urea during its manufacture is released into the environment during its consumption or application to fields).

- CO<sub>2</sub> emissions from natural gas processing plants are estimated in the Inventory using emissions data from the Greenhouse Gas Reporting Program (GHGRP) petroleum and natural gas systems source category (40 CFR Part 98, Subpart W, also referred to as “Subpart W”). CO<sub>2</sub> that is captured at natural gas processing plants is not reported as an emission under Subpart W, therefore this Inventory approach to estimate emissions does not include this captured CO<sub>2</sub> as an emission from processing plants (Inventory section 3.6). If the CO<sub>2</sub> is then used in a non-EOR industrial or commercial application, the resulting emissions are included in the Carbon Dioxide Consumption section of the Inventory. If it is used for EOR or geologically sequestered, it is implicitly treated as storage in the Inventory.
- CO<sub>2</sub> emissions from fermentation production processes at ethanol plants are considered biogenic and not included as an emission source category in the Energy or Industrial Processes and Product Use (IPPU) sectors in the Inventory. As with other sources, capture and storage of CO<sub>2</sub> from ethanol plants is currently not included in the Inventory.

## 2 2006 IPCC Guidelines for Carbon Dioxide Transport, Injection and Geological Storage

The 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories provides guidance on incorporating CCS into national GHG Inventories.<sup>2</sup> IPCC 2006 subdivides CCS into four components: capture and compression system, transport system, injection system, and storage system.

- Capture and compression system emissions are reported with the source categories where they occur. For example, any emissions from CO<sub>2</sub> capture at a natural gas processing plant is reported under the natural gas systems source category.
- For transport, the IPCC provides Tier 1 default factors for leaks and other fugitive emissions associated with pipeline transport of CO<sub>2</sub>.
- The IPCC does not provide a default method or emission factors for CO<sub>2</sub> injection emissions (e.g., fugitive emissions from compression equipment), but the guidance states that any fugitives from compression at the storage site should be measured and reported.
- The IPCC does not provide a default method or emission factors for geological storage of CO<sub>2</sub>, and instead recommends that countries develop Tier 3 monitoring approaches to track any potential post-injection release of CO<sub>2</sub> to the atmosphere. This category is not currently included in the Inventory, though some information on geological storage is discussed in the Inventory as noted above. IPCC Tier 3 procedures for estimating and reporting on geological storage are summarized below.
  - Confirm that geology of a storage site has been evaluated and that local and regional hydrogeology and leakage pathways have been identified.

<sup>2</sup> 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 5: Carbon Dioxide Transport, Injection and Geological Storage. [https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2\\_Volume2/V2\\_5\\_Ch5\\_CCS.pdf](https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_5_Ch5_CCS.pdf)

- Confirm that the potential for leakage has been evaluated through a combination of site characterization and realistic models that predict movement of CO<sub>2</sub> over time and locations where emissions might occur.
- Ensure that an adequate monitoring plan is in place. The monitoring plan should identify potential leakage pathways, measure leakage, and/or validate and update models as appropriate.
- Report both CO<sub>2</sub> injected for storage, and potential associated CO<sub>2</sub> emissions associated with storage operations, corresponding to the storage site.
- Furthermore, under IPCC guidance, if CO<sub>2</sub> is captured in one country and exported for storage in a different country then the exporting country should report the amount of CO<sub>2</sub> captured, any emissions from transport and/or temporary storage that takes place in their borders and the amount of CO<sub>2</sub> exported. The exporting country would not count the CO<sub>2</sub> exported as an emission in their Inventory.

### 3 Analysis of Available Data

#### 3.1 GHGRP

Carbon capture and geologic sequestration data collected from the GHGRP is available as a possible supplemental source of information that could be used in the Inventory.

Under the Suppliers of CO<sub>2</sub> source category of the GHGRP (40 CFR Part 98, Subpart PP, also referred to as “Subpart PP”), EPA receives data from facilities with CO<sub>2</sub> production wells (natural CO<sub>2</sub> domes<sup>3</sup>) and other industrial facilities that extract or capture CO<sub>2</sub> streams. Importers and exporters of bulk CO<sub>2</sub> are required to report if total combined imports/exports of CO<sub>2</sub> and other GHGs exceed 25,000 tons CO<sub>2</sub>e per year. Reporters provide information on the mass of CO<sub>2</sub> captured or extracted, data used to calculate that amount, and information on the amount of CO<sub>2</sub> that is supplied to various end use categories. Currently, some Subpart PP data are used to provide estimates in Box 3-6 of the Inventory. Table 1 shows data from Subpart PP.

*Table 1. Data from GHGRP Subpart PP for 2010-2020 (million metric tons CO<sub>2</sub>)<sup>a</sup>*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>CO<sub>2</sub> Produced (Natural Domes)</b>	<b>48.7</b>	<b>49.9</b>	<b>50.3</b>	<b>49.8</b>	<b>50.9</b>	<b>45.7</b>	<b>38.7</b>	<b>40.7</b>	<b>38.7</b>	<b>39.0</b>	<b>27.2</b>
Transferred to Food and Beverage	1.9	1.5	1.4	1.5	1.6	1.6	1.5	1.2	1.2	1.4	1.7
Transferred to EOR	44.8	48.4	48.9	47.0	46.2	41.8	36.5	38.1	36.4	37.4	25.3
Transferred to Other <sup>b</sup>	2.0	0.1	0.0	1.4	3.1	2.3	0.8	1.4	1.2	0.1	0.2
<b>CO<sub>2</sub> Captured (Industrial Sources)</b>	<b>16.1</b>	<b>16.3</b>	<b>16.0</b>	<b>18.6</b>	<b>20.5</b>	<b>19.1</b>	<b>17.3</b>	<b>19.3</b>	<b>19.8</b>	<b>22.4</b>	<b>17.5</b>
Transferred to Food and Beverage	2.5	2.6	2.6	2.7	2.9	3.4	3.3	3.5	3.0	3.5	3.3
Transferred to EOR	9.9	9.9	9.3	12.2	13.1	12.2	10.2	11.5	12.0	14.7	9.9
Transferred to Other <sup>b</sup>	3.6	3.9	4.1	3.7	4.5	3.6	3.9	4.3	4.7	4.2	4.3

<sup>3</sup> The IPCC does not make specific mention of CO<sub>2</sub> produced from natural domes; however, it could be considered that CO<sub>2</sub> produced from naturally-occurring reservoirs is an anthropogenic activity (i.e., it would not have been emitted otherwise).

<sup>a</sup> As of August 7, 2021.

<sup>b</sup> Includes cleaning and solvent use, fumigants and herbicides, transportation and storage of explosives, fire-fighting equipment, industrial and municipal water/wastewater treatment, pulp and paper, metal fabrication, greenhouse plant growth, geologic sequestration, and unknown (which may include EOR).

The Geologic Sequestration of Carbon Dioxide source category of the GHGRP (40 CFR Part 98, Subpart RR, also referred to as “Subpart RR”) provides a mechanism for facilities to report the amount of CO<sub>2</sub> sequestered in geologic formations on an annual basis to EPA. Subpart RR outlines specific requirements, including development and implementation of a site-specific monitoring, reporting and verification (MRV) plan, for facilities to adhere to in order to report geologic sequestration under Subpart RR. Subpart RR includes wells that inject a CO<sub>2</sub> stream for long-term containment in subsurface geologic formations and wells permitted as an UIC Class VI well for large-scale geologic sequestration. Facilities report data on the amount of CO<sub>2</sub> received, data used to calculate the amount, and the source of the received CO<sub>2</sub> (if known); various mass balance equation inputs (mass of CO<sub>2</sub> injected, recycled, emitted, produced, equipment leaks, surface leakage, and entrained CO<sub>2</sub> in produced hydrocarbons), the amount of CO<sub>2</sub> sequestered, data used to calculate the inputs/amounts, and an annual monitoring report. EPA considers Subpart RR data to satisfy the requirements of an IPCC Tier 3 approach. Currently Subpart RR data are not incorporated in the Inventory. Tables 2 and 3 provide data from Subpart RR of the GHGRP.

*Table 2. Data from GHGRP Subpart RR for 2016-2020 (metric tons CO<sub>2</sub>)<sup>a</sup>*

	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>
CO <sub>2</sub> sequestered	3,090,607.7	5,958,384.9	7,661,556.1	8,332,419.7	6,764,879.0
CO <sub>2</sub> equipment leaks	9,818.0	9,577.0	11,022.6	15,621.0	51,029.0
CO <sub>2</sub> surface leaks	0.0	0.0	0.0	0.0	22,973.9

<sup>a</sup> As of August 7, 2021.

*Table 3. Data from GHGRP Subpart RR for 2020 by Facility (metric tons CO<sub>2</sub>)<sup>a</sup>*

<b>Facility</b>	<b>CO<sub>2</sub> sequestered</b>	<b>CO<sub>2</sub> equipment leaks</b>	<b>CO<sub>2</sub> surface leaks</b>
Archer Daniels Midland	521,581.4	628.4	0.7
Core Energy	213,515.2	2,841.2	0.0
Denver Unit	2,812,135.3	41,933.6	0.0
Hobbs Field	2,138,919.2	5,572.0	0.0
North Burbank Unit	660,309.6	53.8	22,973.9
Shute Creek	418,418.3	0.0	0.1
<b>Total:</b>	<b>6,764,879.0</b>	<b>51,029.0</b>	<b>22,974.7</b>

<sup>a</sup> As of August 7, 2021.

Facilities that conduct EOR are not required to report under Subpart RR unless the owner or operator chooses to opt-in and report under Subpart RR. However, facilities not reporting under subpart RR that inject CO<sub>2</sub> underground for EOR, or for any purpose other than geologic sequestration, report data on CO<sub>2</sub> received for injection under the Injection of CO<sub>2</sub> source category of the GHGRP (40 CFR Part 98, Subpart UU, also referred to as “Subpart UU”). Subpart UU does not require an MRV plan or the mass balance data for geologic sequestration that are reported under subpart RR.

### 3.2 Other Data Sources for Supply and Sequestration Estimates

CCS data from independent, publicly available sources, with similar, but not complete results, is available. In aggregate these data may not align with the GHGRP, but they could provide additional information or be used to confirm reported data. For example:

- Several online databases, such as the Global CCS Institute Global Status Report<sup>4</sup> and the U.S. Department of Energy National Energy Technology Laboratory Carbon Capture and Storage Database<sup>5</sup>, include information on CO<sub>2</sub> captured from industrial sources for CO<sub>2</sub>-EOR or other storage.
- Many corporate annual reports and 10-Ks provide information on CO<sub>2</sub> captured for CO<sub>2</sub>-EOR and/or storage. Also, considerable information is provided on company websites.
- Facilities supported by government R&D funding that are capturing CO<sub>2</sub> generally report such information in government reports.

It is important to note that such information (such as that in a company's annual report or reported at a conference) will change from year to year.

## 4 Methodology Update Considerations

EPA is considering methodologies for using GHGRP and other data to characterize and incorporate estimates of the different components of CCS in the Inventory.

### 4.1 CO<sub>2</sub> Emissions from Capture

In general, for sources where CO<sub>2</sub> capture is occurring, emissions associated with that capture (i.e., from the capturing process) are included in the Inventory. For example, emissions occurring at natural gas processing plants are reported to GHGRP and incorporated into the Inventory.

### 4.2 CO<sub>2</sub> Emissions from Pipeline Transport

EPA could use IPCC default Tier 1 emission factors to estimate CO<sub>2</sub> emissions from pipeline transport. In this approach, the leakage emissions estimates from pipeline transport are assumed to be independent of throughput and are based on distance (length) of pipeline.

To estimate the length of pipelines, EPA could either:

- Include only CO<sub>2</sub> transport associated with receiving Subpart RR facilities. The length of CO<sub>2</sub> pipeline from capture to the sequestration site is not required to be reported by Subpart RR facilities, so this approach would require substantial independent analysis; or,
- Estimate emissions associated with the entire CO<sub>2</sub> pipeline network in the United States. This could be done through a methodology such as: (1) Gather information on the lengths of CO<sub>2</sub> pipeline in the United States from the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, and (2) Estimate emissions from the entire pipeline system.

The approach used would somewhat depend on how emissions were accounted for from the different CO<sub>2</sub> capture sources. If emissions are accounted at the source for all capture except for sequestration,

<sup>4</sup> <https://www.globalccsinstitute.com/resources/global-status-report/>

<sup>5</sup> <https://www.netl.doe.gov/coal/carbon-storage/worldwide-ccs-database>

the first approach might be the most appropriate so as to avoid double counting of emissions. If emissions for all captured CO<sub>2</sub> are netted out or not completely accounted for at the source, then the second option might be more relevant.

#### 4.3 CO<sub>2</sub> Emissions from Injection

As noted above, the IPCC Guidelines do not provide a default method for estimating emissions from CO<sub>2</sub> injection. GHGRP reporters provide an estimate of fugitive emissions from CO<sub>2</sub> injection systems (assumed to be under CO<sub>2</sub> equipment leaks) under Subpart RR. This information could be used to estimate national emissions associated with CO<sub>2</sub> injection in the Inventory. The GHGRP data include injection related emissions from sequestration sites, and emissions from the equipment between the flow meter used to measure injection quantity and the injection wellhead which would be included in the Inventory. Any fugitive CO<sub>2</sub> emission between the capture facility fence line and the injection point would not be captured using this method but could potentially be captured as part of transport emissions discussed above.

#### 4.4 CO<sub>2</sub> Sequestration

GHGRP reporters under Subpart RR provide an estimate of storage and any leakage of CO<sub>2</sub> from storage (assumed to be under CO<sub>2</sub> surface leaks in the tables above), which could be incorporated into the Inventory.

However, while reporting of emissions associated with CO<sub>2</sub> sequestration sites (i.e., leakage) is fairly straightforward, there are challenges in accurately accounting for CO<sub>2</sub> sequestration in the Inventory. The IPCC approach calls for subtracting the amount of CO<sub>2</sub> sequestered from the source category where it was captured. In order to do this we would need a tracking of the source (e.g. natural gas processing plant or ethanol production facility) of CO<sub>2</sub> that is reported under Subpart RR and could make the following updates to the Inventory accordingly:

- If the CO<sub>2</sub> is from natural gas processing (covered under Subpart W) there would be no need for adjusting the Inventory since those emissions are already netted out.
- If the CO<sub>2</sub> is from natural domes there would be no adjustment needed to the Inventory since it would be a transfer from one sink to another.
- If the CO<sub>2</sub> was from any other industrial process source we could adjust the Inventory to subtract that CO<sub>2</sub> capture from the source in question. This would include CO<sub>2</sub> captured from biogenic sources such as ethanol facilities.

For each above update, any subsequent geologic seepage would be reported under RR and taken into account in the Inventory.

However, the challenges with this approach include:

- **Determining if the source of the captured/supplied CO<sub>2</sub> is from natural domes or Industrial sources.** CO<sub>2</sub> capture/supply can come from both industrial sources (e.g. natural gas processing plants) and natural CO<sub>2</sub> domes. Because CO<sub>2</sub> pipelines often transport CO<sub>2</sub> from a mix of sources, it can be difficult to determine the source category of captured CO<sub>2</sub> (e.g., for 2020 Subpart RR reporters, Denver Unit and Hobbs field are in the Permian Basin which has several CO<sub>2</sub> sources connected to the system including natural CO<sub>2</sub> domes and industrial CO<sub>2</sub> sources). Due to the

interconnected nature of CO<sub>2</sub> pipelines in the United States, determining the exact source of capture, and therefore assigning reductions to the proper source category in the Inventory, is a challenge and will continue to be as additional facilities report under Subpart RR.

- **For industrial sourced CO<sub>2</sub> aligning end uses to the IPCC source category used in the Inventory.** Once the source of the captured carbon and the end use are identified, the use of the CO<sub>2</sub> must be categorized and aligned with IPCC source categories as best as possible. Then, EPA must determine if the captured carbon should be removed (or it is already removed) and if so, from which source category.

Examples of how these challenges could be approached are explored below.

#### 4.4.1 Examples

There is an Archer Daniels Midland ethanol plant that captures biogenic CO<sub>2</sub> as the source of CO<sub>2</sub> sequestered. This biogenic CO<sub>2</sub>, absent capture, would not be included in the Inventory as an energy related emissions source.<sup>6</sup> Where this CO<sub>2</sub> is captured by the ethanol plant before it can be released to the atmosphere, it is a CO<sub>2</sub> emission reduction. This approach is consistent with the IPCC Guidance, which states: “Once captured, there is no differentiated treatment between biogenic carbon and fossil carbon. Emissions and storage of both biogenic and fossil carbon will be estimated and reported.” The biogenic CO<sub>2</sub> captured may be from biomass fermentation and not necessarily a combustion source, however, the CO<sub>2</sub> captured for sequestration could be subtracted from the energy source category that include ethanol facilities such as Manufacturing Industries and Construction: Chemicals.

For Hobbs Field and Denver Unit, the exact origin of the sequestered CO<sub>2</sub> is not able to be tracked through the GHGRP (see above). In this instance, EPA is considering approaches for estimating the source of the CO<sub>2</sub>. The approach would need to distinguish between natural dome CO<sub>2</sub> sources and specific industrial CO<sub>2</sub> sources, and where applicable, make it clear that the quantity of CO<sub>2</sub> that was captured by an industry was not emitted to the atmosphere. Table 4 provides an example of how GHGRP data could be used to develop an estimate of a proportion of CO<sub>2</sub> from various sources. Specific options are discussed in section 4.4.2 below.

*Table 4. Data from GHGRP Subpart PP for 2020 Used to Develop Proportions of CO<sub>2</sub> Sources (metric tons CO<sub>2</sub>)<sup>a</sup>*

	<b>Capture/Supply</b>	<b>EOR Use</b>	<b>Food &amp; Beverage Use</b>	<b>Other Use</b>
Industrial Sources (MMT CO <sub>2</sub> ) <sup>b</sup>	17.5	9.9	3.3	4.3
Industrial Sources (% of Total)	39%	28%	66%	95%
CO <sub>2</sub> Domes (MMT CO <sub>2</sub> ) <sup>b</sup>	27.2	25.3	1.7	0.2
CO <sub>2</sub> Domes (% of Total)	61%	72%	34%	5%

<sup>a</sup> As of August 7, 2021. Note: Totals may not sum due to rounding.

<sup>b</sup> MMT = million metric tons

EPA could use the amount of CO<sub>2</sub> captured/supplied from industrial versus natural domes and assume that CO<sub>2</sub> stored in subpart RR has the same sources (i.e., assume that in 2020 ~39% of the sequestered CO<sub>2</sub> comes from an industrial source and ~61% comes from natural CO<sub>2</sub> domes).

<sup>6</sup> Emissions from Ethanol Consumption are not included specifically in summing Energy sector emission totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry sector of the Inventory.

#### 4.4.2 Methodology Options

Drawing on the examples discussed above, EPA is considering options for attributing CO<sub>2</sub> sequestration in the Inventory. Two options are discussed below but EPA is also requesting recommendations for other options not listed.

##### *Option 1: Assign CO<sub>2</sub> Storage for Each Storage Site to the Major Source of CO<sub>2</sub> Emissions Capture*

Assumptions could be made about the major source of CO<sub>2</sub> capture based on industry data or looking at pipeline networks or through comprehensive literature review.

For example, both the Hobbs Field and Denver Unit are in the Permian Basin. Based on the analysis presented above in Table 4, 39% of the CO<sub>2</sub> sequestered in 2020 came from industrial sources.

According to the Global CCS Institute Global Status Report, the largest sources of CO<sub>2</sub> capture that are fed to the Permian Basin storage sites are from two natural gas processing plants, i.e., Century Gas Plant and Terrell Natural Gas Processing Plant (formerly Val Verde Natural Gas Plants).<sup>7</sup> Therefore, it can be determined that since natural gas processing is the major source of CO<sub>2</sub> in the Permian Basin, the 39% industrial source CO<sub>2</sub> removals from that site belong in the natural gas processing source in Inventory reporting. The remaining 61% would be assumed to come from CO<sub>2</sub> domes.

As another example, for the Archer Daniels Midland facility it could be assumed that 100% of the CO<sub>2</sub> captured and sequestered is from an ethanol facility.

While this method does not accurately represent all sources of capture, it presents a straightforward approach to allocate reductions, which is replicable for future project sites and consistently ensures that mass balances for each project type are preserved in the major source category. However, this approach runs the risk of causing underestimation in emissions from the major source of CO<sub>2</sub>, since all the deductions would be allocated, in the Hobbs Field and Denver Unit case, to natural gas processing. This approach seems the most sustainable and easiest to implement, but there will be some sacrifices in accuracy at the source category level, particularly if sequestration becomes more common and the number of Subpart RR reporting facilities increases.

##### *Option 2: Assign Deductions Based on a Split Between All Possible Industrial Sources.*

EPA is also considering making subtractions (or carbon removals) for the 39% industrial source CO<sub>2</sub> from all industries for which carbon capture projects are operational that may feed into a sequestration site. The total amount of industrial source CO<sub>2</sub> captured for geologic storage in the United States would be equally (or by some factor) subtracted from industry/sectors which provide CO<sub>2</sub> to sequestration sites as gleaned from Subpart RR or through industry research. Major sources include natural gas processing, ethanol fermentation, and hydrogen and ammonia production. The reporting category in the Inventory would be based on industry (e.g., natural gas processing, ethanol fermentation, hydrogen production, ammonia production). The remaining 61% would be assumed to come from CO<sub>2</sub> domes.

While this approach subtracts emissions from a larger industry base representing the entire US, reflecting a potentially more accurate representation of CO<sub>2</sub> sources in the United States, it is difficult to ascertain all sources of capture for a specific sequestration site from publicly available information.

Reporting thresholds may also be a concern; if they are not met this approach is not sustainable year-

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<sup>7</sup> <https://www.globalccsinstitute.com/resources/global-status-report/>



over-year. In addition, subtracting CO<sub>2</sub> captured (either equally or by some proportion across emitting source categories), may lead to underestimation or overestimation of emissions from certain source categories. Lastly, maintaining mass balance across several inventory reporting categories based on assumptions may prove challenging and lead to inconsistency between Inventory cycles.

#### 4.4.3 Treatment of EOR in the Inventory

EPA is also considering options for the treatment of EOR in the Inventory. Facilities not reporting under Subpart RR, but which inject CO<sub>2</sub> underground for EOR, or for any purpose other than geologic sequestration, report data on CO<sub>2</sub> received for underground injection under Subpart UU of the GHGRP. Subpart UU does not require an MRV plan or the mass balance data for geologic sequestration reported under subpart RR, therefore reported quantities of CO<sub>2</sub> sequestered are not available for these facilities. However, EOR facilities may opt to report under Subpart RR instead of Subpart UU, and therefore would be required to have an MRV plan and follow the mass balance approach within Subpart RR, which relies on data related to the amount of CO<sub>2</sub> injected, among other data.<sup>8</sup>

Potential approaches for the treatment of EOR in the Inventory could include maintaining the current approach of treating it as long-term sequestration, which assumes comparability to reporting under Subpart RR, or treating it as other storage not reported to Subpart RR that is assumed to be emitted. As noted above, while Subpart RR is assumed to meet the requirements of an IPCC Tier 3 approach for CO<sub>2</sub>. The 2006 IPCC Guidelines indicates that geological CO<sub>2</sub> storage may take place either at sites where the sole purpose is CO<sub>2</sub> storage, or in tandem with EOR. However, they also indicate that some of the emission pathways from EOR operations differ from those for geological CO<sub>2</sub> storage which would presumably have to be accounted for as part of a Tier 3 approach.

Any changes in treatment of EOR would mainly impact sources where the Inventory currently is netting out or not reporting emissions from the source including EOR CO<sub>2</sub> from natural gas processing and from natural domes.

Subpart UU only accounts for the amount of new CO<sub>2</sub> received for injection and does not opine on the fate of that CO<sub>2</sub>. Note that treating all EOR CO<sub>2</sub> as a release to the atmosphere in the Inventory would overestimate actual CO<sub>2</sub> emissions given that the process of EOR can lead to incidental storage of most CO<sub>2</sub> that is received for injection. In an EOR project, a portion of the injected CO<sub>2</sub> gets trapped in the reservoir in the form of one or more CO<sub>2</sub> trapping mechanisms (stratigraphic trapping, dissolution in residual oil/brine, residual trapping due to hysteresis, and mineral trapping). The remaining portion of the CO<sub>2</sub> is produced along with hydrocarbons and brine through the production wells, which will be separated and re-injected back into the reservoir along with newly received CO<sub>2</sub>. Volumes of CO<sub>2</sub> that are recycled at the last stage of the EOR project can be re-injected back into the reservoir as wells are shut-in or transported to another EOR project. Over the life of an EOR project, the amount of newly received CO<sub>2</sub> decreases as the quantity of CO<sub>2</sub> produced from the reservoir through recycling increases. The geology of an oil and gas reservoir can effectively trap CO<sub>2</sub> underground for thousands of years.

However, long-term sequestration depends on appropriate site selection, characterization,

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<sup>8</sup> We note that CSA/ANSI ISO 27916:2019, “Carbon Dioxide Capture, Transportation and Geological Storage—Carbon Dioxide Storage Using Enhanced Oil Recovery (CO<sub>2</sub>-EOR)”, establishes a protocol for documenting the containment of CO<sub>2</sub> injected in an EOR operation and quantifying the amount of CO<sub>2</sub> that is stored in association with that operation. However, comprehensive data are currently not publicly available on projects that are using the CSA/ANSI ISO 27916:2019 methodology and their storage amounts.

management, and monitoring. EOR projects currently reporting under Subpart RR with approved MRV plans, which require these elements have demonstrated successful sequestration of CO<sub>2</sub>.

## 5 QUESTIONS FOR STAKEHOLDERS

### 5.1 Data Sources

The GHGRP has data reported starting in 2010 on CO<sub>2</sub> supply, and starting in 2016 on geologic sequestration. Several other public sources of data were also identified.

1. Are the data sources identified appropriate?
2. Are there other sources of data EPA should be considering?
3. For years prior to 2010 are data sources available on CO<sub>2</sub> supply? Is that data consistent with GHGRP data? If so, how should it be combined?

### 5.2 Methodology

1. EPA has identified potential options for incorporating CO<sub>2</sub> transport, injection, and sequestration into the Inventory. One important factor in EPA's consideration, in addition to accurate data estimation, is that the approach selected be feasible in future years as more geologic sequestration sites begin reporting to Subpart RR. Are the methodology options for incorporating GHGRP data into the inventory appropriate given IPCC guidelines on CO<sub>2</sub> Transport, Injection, and Geologic Storage and available data from the EPA GHGRP? Should EPA consider alternative methods, particularly for assigning CO<sub>2</sub> emission reductions as a result of geologic sequestration to an emitting source category?
2. Would developing this percent split between CO<sub>2</sub> dome and industrial CO<sub>2</sub> each year be most appropriate (see Table 4), or would it be appropriate to use averages over set periods if there is little variability?
3. Should EPA consider a more site-specific approach or more generic approaches?
4. Where should CO<sub>2</sub> capture be counted, in particular for industrial sources? (For example, for ethanol fermentation CO<sub>2</sub>, which source category?)
5. Use of direct air capture technologies is currently limited but may increase in future years. EPA seeks stakeholder feedback on how the inventory should reflect this captured CO<sub>2</sub>.
6. Are there are resources or data that EPA should consider related to captured CO<sub>2</sub> used for EOR and non-EOR end uses (e.g., industrial applications) as part of determining if captured emissions are ultimately sequestered or emitted, consistent with IPCC guidance?