

Summary of Expert Review Comments and Responses: Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021

Expert Review Period (Fall 2022) U.S. Environmental Protection Agency Office of Atmospheric Programs Washington, D.C.

Preface	3
Chapters 1. Introduction, 2. Trends, 9. Recalculations and Improvements	4
Chapter 3. Energy	4
Chapter 4. IPPU	14
Chapter 5. Agriculture	21
Chapter 6. LULUCF	26
Chapter 7. Waste	29
Appendix A: List of Reviewers and Commenters	49
Appendix B: Dates of Review	50
Appendix C: EPA Charge Questions to Expert Reviewers	51
Chapter 3. Energy	51
Chapter 4. Industrial Processes and Product Use (IPPU)	52
Chapter 5. Agriculture	53
Chapter 6. Land Use, Land-Use Change, and Forestry (LULUCF)	54
Chapter 7. Waste	55
Appendix D: Supplemental Technical Memos to Expert Reviewers for Energy, IPPU, and Waste Sector	⁻ s 58

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: 1990-2021* for a preliminary Expert Review of estimates and methodological updates prior to release for Public Review. The Expert Review of sectoral chapters was 30 days 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 87 unique comments on as part of the Expert Review process. Generally, the verbatim text of each comment extracted from the original comment letters is included in this document, arranged by sectoral chapters. In a few instances, comments are summarized, in particular where feedback focused on implementing minor editorial revisions to improve clarity of the report narrative. 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.

Chapters 1. Introduction, 2. Trends, 9. Recalculations and Improvements

Chapters 1, 2 and 9 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

Comment 1: Fossil Fuel Combustion: CO2

The information and discussion in this section are able to be followed by the reader and are clearly stated. The figures and tables are explained. Sources of information are given. No recommendations for additional information to be added to aide in providing transparency and clarity.

Response: EPA notes this feedback.

Comment 2: Fossil Fuel Combustion: CH4 and N2O Stationary Sources

The overall methodology was clear and transparent. The figures and tables are explained. Sources of information are given. No recommendations for additional information to be added to aide in providing transparency and clarity.

Response: EPA notes this feedback.

Comment 3: Non-Energy Uses of Fossil Fuels

- a. Data sources are well documented, measures were taken to avoid double counting, uncertainty and deficiencies are discussed as well as some future improvements. 2021 emissions data for international bunker fuels and wood biomass and biofuels consumption are not available, so 2020 data were used for the time being. Even though the data were not available for these two sectors, the outlined methodology on emissions estimation is clear and transparent. Future emissions improvements are discussed and if implemented, will result in more accurate emissions estimates.
- b. On Page 3-41, it says that " non-energy use emissions increased by 44.3% from 2020 to 2021, mainly due to an increase in industrial fuel use (specifically in the cocking coal and HGL industries) potentially caused by a bounce back in production following the early effects of the COVID-19 pandemic". However, the CO₂ emissions estimated in 2021 (156.2 MMT CO₂ Eq.) from non-energy use fossil fuel consumption is still considerably higher than the pre-pandemic emissions of 118.3 and 116.0 MMT CO₂ Eq in 2018 and 2019, respectively. Therefore, the 44.3% increase in 2021 cannot only be attributed to the pandemic bounce back. Other factors for this increase need to be discussed as well.

Response: EPA notes the feedback in 3 a. above. For 3 b., with updated values the NEU increase from 2020 to 2021 is only 17.6% so more in line with pre-pandemic levels. Also, more information was provided in terms of what is driving the increase. See pg. 3-51 of the Final Inventory report for more details.

Comment 4: Incorporating Carbon Capture & Storage Data

- a. The methodology and the differences between options was clear and presented a transparent conundrum of which direction would be best. It was additionally helpful that the IPCC guideline section was included for completeness.
- b. A discussion on how natural domes are applicable would have been helpful compared to industry sources. For completeness, providing a list of sources for the industrial categories pursued would assist in identifying where additional sources could be used or incorporated.

Response: EPA notes the feedback and continues to examine ways to incorporate carbon capture and storage data in the Inventory.

Comment 5: Adding when Transportation overtook electric power generation as largest emission source

Pg 3-4 of ER Draft Energy Chapter lines 10-11: Perhaps worth mentioning when this ceased to be the case?

Response: Text has been edited on pg. 3-9 of the Final Inventory report to add that transportation sector emissions exceeded electric power sector emissions in 2017.

Comment 6: Net Generation Clarification

Pg 3-4 of ER Draft Energy Chapter lines 14: Is "Total Electric Power Generation" net generation?

Response: Yes, this is referring to net generation. Text on pg. 3-9 of the <u>Energy Chapter (Chapter 3)</u> in the <u>Final Inventory report</u> has been edited to indicate it is total net electric power generation.

Comment 7: Source Clarification

Pg 3-4 of ER Draft Energy Chapter lines 14-16: Is the source of this data MER Data?

Response: Yes, the source of the data is the EIA MER. The text on pg. 3-9 of the <u>Energy Chapter</u> (<u>Chapter 3</u>) in the Final Inventory report has been edited to add a reference to the EIA MER as the source of this data.

Comment 8: Source Clarification

Pg 3-5 of ER Draft Energy Chapter lines 3-9: EIA citation below (2021c) is *Electric Power Annual*. Would MER be a more appropriate source for this information, given that this seems to be fuel consumption?

Response: The references in that section of the report (see pg. 3-10 of the <u>Energy Chapter (Chapter 3)</u> in the Final Inventory report) have been updated. Fuel use data now references the EIA MER while electricity use data still reference the Electric Power Annual.

Comment 9: Source Clarification

Pg 3-7 of ER Draft Energy Chapter Box 3-1: EIA citation 2022c references to Quarterly Coal Report, is this correct?

Response: That reference was incorrect. The text on pg 3-12 of the <i>Energy Chapter (Chapter 3) in the *Final Inventory report has been updated to reference the EIA MER..*

Comment 10: Source Clarification

Pg 3-8 of ER Draft Energy Chapter Footnote 6: Missing Reference

Response: The references have been updated (see Footnote 11 on pg 3-13 of the <u>Energy Chapter</u> (Chapter 3) in the Final Inventory report.

Comment 11: Clarification in naming convention

Pg 3-10 of ER Draft Energy Chapter lines 6-11: Might help to be consistent in naming convention between these two. I.e., either "CH4 and N20" or "methane and nitrous oxide". Several instances of this convention throughout the chapter.

Response: The report was checked for consistency, where the names are used in the body of a sentence chemical formulas CH_4 and N_2O are used. Where gases are used at the start of a sentence names are spelled out directly as Methane and Nitrous Oxide.

Comment 12: Source Clarification

Pg 3-18 of ER Draft Energy Chapter lines 10: Source EIA 2020g, not included in references

Response: The references have been updated (see pg. 3-23 of the <u>Energy Chapter (Chapter 3)</u> in the <i>Final Inventory report).

Comment 13: Source Clarification

Pg 3-28 of ER Draft Energy Chapter lines 27-30: Reference: EIA (2007) Personal Communication. Joel Lou, Energy Information Administration and Aaron Beaudette, ICF International. *Residual and Distillate Fuel Oil Consumption for Vessel Bunkering (Both International and Domestic) for American Samoa, U.S. Pacific Islands, and Wake Island*. October 24, 2007.

IES team has suggested that this reference is incorrect since they have never had bunker data for American Samoa, U. S. Pacific Islands, and Wake Island.

Response: EPA will look into this reference and update or provide the appropriate source in future reports.

Comment 14: Source Clarification

Pg 3-72 of ER Draft Energy Chapter lines 14-21: Source Lindstrom 2006, Perry Lindstrom retired from EIA last year. It could be beneficial to have a conversation about updating this citation to a new data source going forward.

Response: EPA agrees it would be beneficial to update this reference. EPA will examine other data sources for future reports.

Comment 15: Biodiesel data update

Pg 3-73 of ER Draft Energy Chapter Table 3-55: The biodiesel number was correct as of whichever MER they drew it from but it has since been updated to 218 trillion Btu for 2021. <u>https://www.eia.gov/totalenergy/data/monthly/pdf/sec10_6.pdf</u>

Response: The biodiesel data in Table 3-114 on pg 3-124 of the <u>Energy Chapter (Chapter 3)</u> in the Final Inventory report has been updated to the latest MER for the final report.

Comment 16: Woody biomass data discrepancy

Pg 3-75 of ER Draft Energy Chapter lines 3-10: Is this (discrepancy between EIA woody biomass consumption data and EPA's acid rain program dataset) still true? If so, let us know if you'd like to discuss this at some point.

Response: That language has been deleted from the report. However, EPA continues to investigate woody biomass data in both the EIA and EPA data sources.

Comment 17: Reference Question

Pg 3-77 of ER Draft Energy Chapter lines 41-42: EIA 2003, reference does not seem to be used in the chapter, should it be removed?

Response: The unused reference has been removed.

Comment 18: Data question

Pg 3-4 of ER Draft Energy Chapter Table 3-4: Total all sectors line for 2018-2019 – Should it be 135.7? Total all sectors line for 2019-2020 – Should it be 508.1? Total all sectors line for 2021 total – Should it be 4,598.9?

Response: The data has been updated to reflect final data (see Table 3-6 on pg. 3-9 of the <u>Final</u> <u>Inventory report</u>).

Comment 19: US Territories

Pg 3-11 of ER Draft Energy Chapter Footnote 8: Should specify the U.S. Territories.

Response: The different territories included in the data have been specified in Footnote 13 on pg. 3-16 of the <i>Energy Chapter (Chapter 3) in the Final Inventory report.

Comment 20: Consistency

Pg 3-31 of ER Draft Energy Chapter Box 3-3: The word Carbon is capitalized in the last two sentences -The word carbon is not capitalized in first sentence.

Response: The capitalization on pg. 3-35 of the <u>Energy Chapter (Chapter 3)</u> in the Final Inventory report has been removed in the last two sentences to make the language in the report more consistent.

Comment 21: Energy Costs

References are made to the relative costs of coal and natural gas on page 3-5, lines 3-9; page 3-12 lines 25-32; and page 3-13 lines 1-17. On page 3-13 it is noted that the cost of coal rose 66% between 2005 and 2021, based on the EIA Electric Power Annual. However, the role of coal costs in power generation and emissions is more complicated than this implies. Referring to the EIA Coal Data Browser (<u>https://eia.gov/coal/data/browser</u>), the EIA Form 923 Schedule 2 price for coal delivered to the electricity sector in several states in the PJM electricity market showed significant declines between 2015 and 2021.

Cost of Coal Delivered to the Electricity Sector (Dollars/Short Ton)

State	2015	2021	Change (%)
Indiana	51.23	50.41	-2%

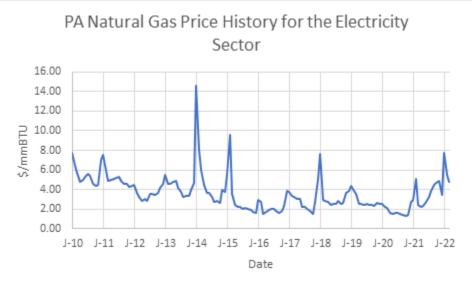
Kentucky	49.01	42.05	-17%
Ohio	53.53	41.44	-29%
Pennsylvania	50.76	39.98	-27%
West Virginia	56.42	49.05	-15%

Converting to energy content (\$/mmBTU) using EIA SEDS values for coal in the electricity sector (MSN code CLEIK), the percentage drops were larger still due to changes in the reported energy content of coal (Figure 1, using Pennsylvania as an example). By the start of the pandemic, the cost per mmBTU had dropped to half its 2015 value.

Because natural gas prices did not experience this cost decrease over this time frame (Figure 2, again using Pennsylvania as an example), low-emitting combined cycle natural gas plants became less competitive in the deregulated PJM market compared to coal, all else being equal. This is important to recognize since it affects the economic viability of cleaner energy resources and leads to greater reliance on high-emitting facilities.







Response: The language in the report (see pg. 3-18 of the <u>Energy Chapter (Chapter 3)</u> in the Final Inventory report) referencing the change in cost of coal and natural gas from 2005 to 2021 has been updated to reflect the most recent data. The change from 2005 was noted because that represents the time frame for when the switching from coal to natural gas began in the electric power sector. However, as per the comment the more recent trends do not necessarily reflect the same trends in prices. The report notes the changes from 2020 to 2021 and the impact on coal and natural gas use. EPA will continue to evaluate the cost changes including at the state level and how they may be impacting fuel switching / use in the electric power sector and reflect that in future reports as necessary.

Comment 22: Units

Page 3-35, Table 3-17, Comparison of Emissions Factors (MMT Carbon/QBtu). It would be useful to include emissions factors as MMT CO₂e/QBTU (or kg/mmBTU) to facilitate comparison with values published on the EPA's GHG Emission Factor Hub. Using MMT C may also confuse some readers to since Table 3-16 is in MMT CO₂e. Alternatively, a footnote could be added with the conversion factor.

Response: The emission factors in the report were still reported as MMT carbon, but footnote 45 was added on pg. 3-39 of the <u>Energy Chapter (Chapter 3)</u> in the Final Inventory report with the conversion factor to convert to CO_2 . The factors were still reported as MMT carbon because it excludes the oxidation factor which varies across the different sources so reporting in terms of carbon puts the values on a more consistent basis.

Comment 23: Word Choice

Page 3-40, Line 26. The word "Program" should be added after "Rain".

Response: That paragraph was deleted for the Final Report.

Comment 24: Fossil fuel combustion

Description of data for energy use in US territories: In the Recalculations Discussion section, it states that the territories data was revised to correct for an error in how the LPG data was pulled. More information about what this error was and why it needed to be corrected might be useful. FHWA proposed methodology: The methodology on adjusting the data to remove the inconsistency appears to be clear. The fuel in Mgal charts from original to revised appear to be trending in opposite directions. If this is the case that the inconsistency has created an inaccurate trend for LDGV and LDGT, then what are the repercussions of this multi-year inaccuracy. Will there need to be modeling resubmissions? Understood that the overall impact of emissions is minimal.

Response: The description of the correction to the US territories data in the recalculations section on pg. 3-40 of the <u>Energy Chapter (Chapter 3)</u> in the Final Inventory report has been updated to provide more information on what the error was and why it needed to be corrected. The Final Report pg. 3-48 outlines the change in methodology to correct for the inconsistency in the FHWA data for LDGV and LDGT. The change did not impact overall emissions just the allocation of fuel use and emissions across the two vehicle types.

Comment 25: Fossil Fuel Combustion: CH₄ and N₂O from Stationary Sources

US specific emission factors: ADEQ is unaware of other, more U.S. specific CH₄ and N₂O emission factor data sources.

Response: EPA notes this feedback and will continue to evaluate CH₄ and N₂O emission factor data sources.

Comment 26: Incorporating CCS Data

Appropriateness of data sources: The data relying on direct reports from GHGRP Subpart PP and Subpart RR seems appropriate as it is the only available data. Other data sources that are publicly available should be reviewed and analyzed, but noted that the projection to the industry could be incomplete. Additional data sources: Additional data sources that could be considered are capacity studies from universities or geology departments, as to what is feasible as a goal.

Data for years prior to 2010: ADEQ does not have available industrial data from prior to 2010. Methodology options for incorporating GHGRP data into the inventory: Option 2 of assigning deductions based on a split between all possible industrial sources seems to be the most reliable and consistent estimate. Although exact, site-specific data is the best option, the long-term estimates for a national database should be consistent and reliable.

Assigning CO₂ emission reductions resulting from geologic sequestration to source categories: Yes, EPA should consider developing approved alternative methods because with Subpart UU site beginning to report, additional guidance will be needed. Also, further categorization on source categories will assist data analysis in this sector.

Use of averages for CO₂ dome and industrial CO₂ over set periods: ADEQ believes that each year percent splits would be the most accurate representation of the data, even with the potential of variability. Smoothing the data with a multi-year average might give remove the potential to see acute trends. Site specific approaches: ADEQ believes that site-specific point source data is the most accurate way to represent the data available. Additionally, the state's reference EPA for many methodologies and guidance. EPA should pursue a generic approach in which a site can follow to obtain the appropriate end goal.

 CO_2 capture: CO_2 capture for industrial sources should be counted at the facility under their industrial code, for the purpose of what it is going towards. For example, an ethanol fermentation of CO_2 for consumption should be categorized as such.

DAC technologies and capture in the inventory: Yes, Arizona universities have strong technologies in direct air capture technologies and as the industry grows, a baseline from early in the trend will aid supporting the technology.

Additional resources or data: Fugitive CO_2 emissions need to be addressed by EPA for industry. GHGs for point sources under the GHGRP are not as consistent due to regulatory requirements and applicable emission factors available.

Response: EPA notes this feedback and continues to evaluate ways to incorporate CCS and DAC in the Inventory. EPA notes the specific feedback regarding use of GHGRP data for CCS reporting including use of site-specific data when available and then allocating across available sources when site-specific

data in not available. EPA will also continue to evaluate new GHGRP data as it becomes available including from any rule updates.

Comment 27: General questions

Transparency and clarity: Energy chapter was very clear. Some comments regarding what underlying data is being referenced, but otherwise no issues with clarity or transparency. Additional data sources: Nothing to add; EIA's energy-use data seems to be well accounted-for

Response: EPA notes this feedback.

Comment 28: Fossil fuel combustion

Transparency and clarity: Discussion on trends was both accurate and clear. No additional comments. Data description and additional sources: With regards to data for energy use in the U. S. territories, EIA has very limited sources. As such, we would say the updates are not adequately described. The petroleum data updates for Puerto Rico are quite good, but not the others. We don't have other sources to compare to.

Response: The description of the correction to the US territories data in the recalculations section on pg. 3-40 of the Energy Chapter (Chapter 3) <u>Final Inventory report</u> has been revised to provide more information and description on the updates made. EPA will continue to evaluate data sources for US territories data.

Comment 29: Appropriateness of data sources and data presentation

Presentation: In several respects the way EPA is presenting the information it has could be improved. For example, as described by EPA in Table 1, some GHGRP subpart PP data (for suppliers of CO₂) is collected and reported in the Inventory at Box 3-6. This data is broken out by the source of the CO₂, as either "produced (natural domes)" or "captured (industrial sources)." Under the second category, EPA splits captured CO₂ into three possible fates: "transferred to food and beverage," "transferred to EOR," or "transferred to 'Other.'" The "Other" category now includes saline/geologic sequestration along with multiple other end uses, most of which do not involve long term or permanent sequestration or storage of captured CO₂.

Response: EPA notes this feedback and continues to evaluate ways to incorporate CCS data in the Inventory. EPA continues to compare the GHGRP subpart PP and RR data to better understand how subpart PP data could be better used / interpreted and presented in the report.

Comment 30: Disaggregation of CO₂ transferred to saline solution

With the amount of geologic sequestration expected to grow in response to the new tax credit enhancements under IRA, accurate tracking of GHG emissions will require EPA to accurately quantify the amount of CO_2 that is transferred to saline sequestration. Rather than continuing to lump that CO_2 into the "Other" category, the table should reflect the difference between geologic storage and end-uses that ultimately result in the release of CO_2 into the atmosphere. Saline sequestration using RR reporting is, as the Agency properly recognizes, a long term (greater than 1,000 years) storage option and is important to distinguish from other end uses in the "Other" category as a specific line item in this table. Response: EPA agrees that the amount of CCS has the potential to increase with new tax credits under IRA. EPA is evaluating ways to incorporate GHGRP subpart PP and RR data in the Inventory reporting including ways to distinguish sequestration from the "Other" category. EPA will also continue to evaluate new GHGRP data as it becomes available including from proposed rule updates.

Comment 31: Combustion of biomass as a fuel source

A second example is the current approach to reporting emissions from bio-based processes such as ethanol production and biomass combustion for energy. As EPA notes, under the 2006 guidance, those emissions are not included as an emissions source category and only "implicitly treated as storage in the Inventory." This is an area where the 2006 approach to reporting included in the IPCC guidelines is severely outdated and has created perverse incentives towards the burning of biomass fuels. EPA has data about these emissions – both at the source level and, in some cases, for the geologic sequestration of captured emissions. Although EPA has declined to establish a unique subpart for reporting the emissions of ethanol fermentation facilities, facilities with significant emissions are still required to report their emissions as other source categories. Facilities that combust biomass as a fuel source are likewise required to report their emissions under subpart C. While CATF encourages the EPA to continually refine its reporting requirements, the availability of data is not an obstacle to EPA's including biomass-originating emissions in the inventory. The Agency should report those totals, alongside and in addition to the IPCC guidance suggested approach. This information can be helpful to IPCC in considering updates to its guidance in order to correct the mistaken notion that these sources do not produce CO_2 emissions.

Response: The EPA reports emissions in the Inventory according to UNFCCC reporting guidelines and requirements, including reporting of biomass CO₂ emissions from combustion as a memo item in the report. EPA is continuing to evaluate ways to treat carbon capture in the Inventory including from ethanol facilities. The GHGRP does collect biomass CO₂ data from combustion under subpart C, however, CO₂ capture at ethanol facilities is often from fermentation CO₂ and would be captured under subpart PP. EPA continues to evaluate ways of incorporating GHGRP subpart PP and RR data in the Inventory.

Comment 32: Reporting emissions from biogenic energy or ethanol production

If EPA's rationale for not reporting emissions from biogenic energy or ethanol production is that they represent zero emissions on a full lifecycle basis, the current science indicates that such a view is incorrect. And, while a lifecycle analysis in theory could be applied to these industrial processes, it is not applied to others, and so accuracy about annual emissions requires reporting "from the source" emissions. In the absence of a life-cycle analysis that has been approved by a federal agency for this accounting, the U.S. must report the actual emissions for each step in the bioenergy process as they occur, and not ignore them. Where carbon capture, utilization, and sequestration are employed in a bioenergy process, to accurately track real progress in climate mitigation, EPA (and the international community) must only count as an emissions reduction the carbon that is secured in long-term storage (e.g., greater than 1,000 years). Storage and utilization processes that do not permanently (and enforceable) secure CO₂ from atmospheric release should be reported as CO₂ emissions and not sinks.

Response: As noted in response to comment 31, per UNFCCC reporting guidelines, the U.S. GHG Inventory reports and organizes emissions and sinks at the source and is not organized to consider a lifecycle analysis or reporting emissions on a product basis. All related emissions are included in the Inventory, just at their source or sector level, and are not attributed on a product life-cycle basis. EPA

continues to evaluate ways to treat CCS in the Inventory. Consideration of CCS reporting will take into account long term storage as a basis for reporting reductions in the Inventory.

Comment 33: Reporting category for DAC

Finally, with the burgeoning of carbon dioxide removal (CDR) methods and projects, for example via direct air capture (DAC) technologies, EPA will need to develop a reporting category for this new industry in the coming years. And the Inventory should evolve accordingly – EPA should report in the Inventory the data it collects, to track removals independently from emissions. For non-DAC CDR methods, the tons removed for a given project should be based on an agency-approved life-cycle analysis, or reported as direct emissions and where sequestered, direct reductions.

Response: EPA continues to evaluate ways to incorporate CCS and DAC data in the Inventory. EPA will also continue to evaluate new GHGRP data as it becomes available including from proposed rule updates for capturing data on DAC.

Comment 34: Attributing CO₂ Sequestration in the Inventory

The two options for attributing CO_2 sequestration in the Inventory under consideration are: 1) assigning storage for each storage site to the major source of CO_2 capture for that site; or 2) assigning deductions based on a split between all possible industrial sources.... as sequestration activity increases, and RR (and VV, we argue) reporting increases with it, EPA will be able to attribute sequestered amounts to industries in the aggregate, without improperly identifying particular sources in an industry. Taking these concerns into account, and noting that they can be overcome, EPA should use its Option 2 on pages 8-9 of the Memorandum to apportion sequestration to the sources of the CO_2 . The Inventory should reflect the most accurate information EPA has, and the Agency does have sufficient information through its GHGRP reporting to assign deductions due to sequestration activity to the industrial category as a whole, based on a split between all possible industrial sources, without improperly releasing CBI. The Agency should count CO_2 capture where it happens and attribute sequestration accordingly.

Response: EPA notes this feedback and continues to evaluate ways to incorporate CCS data in the Inventory. EPA appreciates the feedback regarding use of GHGRP data for CCS reporting including use of source specific data when available and then allocating across available sources (option 2 from Memo) when source specific data in not available. EPA will also continue to evaluate new GHGRP data as it becomes available including any rule updates (e.g., subpart VV data).

Comment 35: Accounting for CO₂ capture

... CATF is of the view that the IPCC approach to biogenic process emissions (that is, to not count them at all unless they are captured) is inconsistent with the current scientific understanding of these emissions' impact on global atmospheric CO₂. Those emissions need to be counted ton for ton in the absence of a governmentally approved (and industry specific) LCA. ... Finally, EPA should not count CO₂ capture as a GHG sink unless the CO₂ is permanently and enforceable sequestered. ... Separately accounting for both the capture and the emissions would facilitate a better understanding of which industries require further abatement. Counting the capture as a sink in the overall GHG inventory distorts the overall contribution to atmospheric CO₂. Only operations that result in permanent and enforceable sequestration are, technically speaking, GHG sinks.

Response: See response to comment #33.

Comment 36: Treatment of DAC in the Inventory

EPA asks how its submission to the Inventory should reflect emissions from DAC technologies. While there is currently no industrial category that encompasses DAC technologies or other emerging CDR options, the tax incentives included in the IRA for technology-based DAC means that it is likely that this industry will develop over the coming years. EPA should prepare for that and seek to collect data about DAC and the fate of captured CO₂. EPA should revise the GHGRP to address DAC and, in the absence of an SIC code for this industry, EPA should define a new source category in the inventory updates to report and track removals, including DAC. CATF supports the finalization of the amended subpart PP with the inclusion of DAC as a unique source category. When finalized, it will provide EPA with the data it needs to accurately account for DAC in the GHG inventory.

Response: See response to comment #33.

Comment 37: Data for sequestration of CO₂ used for EOR

EPA asks whether there are resources or data it should use in determining the ultimate fate of EOR sequestered CO₂. As the Agency notes, at present the CO₂ used in EOR operations is assumed to be sequestered permanently, with the exception of process equipment releases. EPA is correct to assume that EOR operators reporting under the GHGRP's subpart UU do not provide sufficient information about the ultimate fate of the CO₂ they use, due to the absence of monitoring, reporting, and verification requirements under subpart UU. Note that the recently increased tax incentives for EOR may spur additional EOR activity, and EPA must ensure that there is robust data collection to support this. As expressed in its public comments on EPA's proposed amendments to the GHGRP, CATF supports the creation of subpart VV and encourages the EPA to adopt final language making clear that EOR operators must report under subpart VV if they rely on the ISO standard for demonstrating secure storage of CO₂. This will close data gaps and ensure that EOR operators claiming the 45Q tax credit formally comply with the ISO standard. Finalization of subpart VV would obviate the concern, expressed by EPA at page 9 of the 2021 memorandum, that the agency lacks the data necessary to accurately report the quantity of CO₂ sequestered through EOR operations.

Response: EPA continues to evaluate treatment of EOR activities in the Inventory, including considering the sources of CO₂ used for EOR and current treatment of carbon capture from those sources in the Inventory. EPA will also continue to evaluate new GHGRP data as it becomes available including from proposed rule updates (e.g., subpart VV data).

Chapter 4. IPPU

Comment 1: Minerals: Glass Production

The methodology was presented clearly and is easy to understand. Table 1 Soda Ash GHGRP percentage typo, should be 99.2%.

Response: EPA appreciates the close review of the proposed methodology and confirms that the average carbonate mineral content of soda ash for the years 2010 through 2021, as reported to the GHGRP, was 99.0%.

Comment 2: Minerals: Other Processes Uses of Carbonates – Ceramics Production

The methodology was presented clearly and is easy to understand. Typo in the second sentence of Section 4, "Uncertainty". Need to change "surround" to "surrounding".

Response: This typo has been addressed.

Comment 3: Chemicals: Phosphoric Acid Production

The description of how the mining activity time series estimates is calculated pre- and post- 2005 is not very explicit. It states what values the calculations were "based on" but not how those values were actually used. The paragraph about mining activity time series calculations could benefit from some concrete example calculations for each estimation method.

Response: The methodology was clarified in the report text.

Comment 4: Chemicals: Ammonia Production

Generally clear, though it would be nice to see some validation of the back-casting assumptions. See feedback on Charge Question #3 for this section.

Response: As noted in the ammonia improvement memo in Figure 2, comparisons of ammonia natural gas feedstock values for the entire time series were completed. For 1990-2009, a comparison of the calculated feedstock value and limited EIA Manufacturing Energy Consumption Survey (MECS) data was completed. EPA will continue to look for additional data that would assist in validating the methodology refinement.

Comment 5: Metals: Ferroalloy Production

The methodology was presented clearly and is easy to understand.

Response: EPA notes this feedback.

Comment 6: Metals: Lead Production The methodology was presented clearly and is easy to understand.

Response: EPA notes this feedback.

Comment 7: Substitution of Ozone Depleting Substances The methodology was presented clearly and is easy to understand.

Response: EPA notes this feedback.

Comment 8: Nitrous Oxide from Product Uses

The methodology presented is clear and easy to follow. Further literature reviews and studies should be completed with analysis of data to determine more accurate emission factors for each end use.

Response: EPA notes this feedback and continues to research additional data sources.

Comment 9: Electrical Transmission and Distribution The description of how US emissions of SF6 between 1990 and 1999 are calculated from the global emissions would benefit from an example or more detail. Additionally, further details on how the emission factors for non-partners from 2000 to 2021 were determined for each year (both before and after the recalculations) would provide added clarity to this section. The paragraphs on how transmission miles were determined was clear and easy to

follow. The paragraphs on emissions from manufactures, uncertainty, QA/QC, and the comparison to atmospheric measurements was also clear and easy to follow.

Further market research to confirm / modify the facilities not reporting to the GHGRP program should be conducted in addition to adding facilities to the inventory that are known to not be accounted for in the inventory such as the SF6 production plant that operated in Metropolis, Illinois through 2010.

Response: EPA is advancing its review of available data to estimate and report on emissions from SF_6 production over time under the fluorinated production category as conveyed in the Planned Improvements discussion on pg. 4-160 of <u>the Industrial Processes and Product Use Chapter (Chapter 4)</u> of the Final Inventory report, in addition to what we are already reporting from SF6 use under electrical transmission and distribution systems.

Comment 10: Representation of glass production for years 1990 - 2009

Yes, the 2020-2021 time period is a reasonable representation of glass production occurring from 1990-2009

Response: EPA notes this feedback.

Comment 11: USGS data on soda ash production

The use of USGS data on soda ash used for glass production is appropriate since it is more complete than the GHGRP data. The USGS data is more complete because USGS surveys have a 100% response rate from soda ash companies, USGS does not have a reporting threshold, and USGS has data available on soda ash consumption by end-use.

Response: EPA notes this feedback.

Comment 12: Assumption of 100% sodium carbonate in soda ash

Since emissions under the current methodology are calculated based on 2006 IPCC Guidelines, it is more appropriate to continue taking a conservative approach and assuming the soda ash contains 100% sodium carbonate, consistent with the Guidelines. Fix the typo in Table 1 for Soda Ash GHGRP percentage, should be 99.2% according to text.

Response: EPA notes this feedback and clarifies that the 99.2% value for soda ash referred to in this comment is the average carbonate-based mineral mass fraction from GHGRP, averaged across 2010 through 2020. After consideration, the averaged value for the years 2010 to 2014 (98.7%) was used to determine the average carbonate-based mineral mass fractions because that period was deemed to better represent historic glass production from 1990 to 2009.

Comment 13: Assumption of 10% carbonate content value for total clay consumption Additional sources of carbonate content per type of clay are currently not available. The IPCC value of 10% is reasonable to assume.

Response: EPA notes this feedback.

Comment 14: Clay usage – assumption of 85% limestone and 15% dolomite

Arizona DEQ does not have local data describing the relative consumption of limestone and dolomite used as carbonate inputs.

Response: EPA notes this feedback.

Comment 15: Completeness of USGS dataset for number of operations and tonnage of clay It is not known if additional data is available on the response rate over the time series.

Response: EPA notes this feedback.

Comment 16: Additional data on total amount of clay, summed across clay types, sold/used by end use

Arizona DEQ does not have local data describing the amount of clay sold/used by end use.

Response: EPA notes this feedback.

Comment 17: consistency and accuracy with direct emissions from ammonia production

TFI submitted comments on October 6, 2022 regarding the EPA proposal entitled, "Revisions and Confidentiality Determinations for Data Elements Under the Greenhouse Gas Reporting Rule" (Docket ID No. EPA-HQ-OAR-2019-0424), expressing support for calculating only direct emissions from Subpart G facilities in order to ensure consistency among the various sectors regulated under the GHGRP. Toward that end, TFI encourages EPA to promote consistency and to accurately reflect direct emissions from ammonia production across GHG inventory protocols.

Response: EPA notes there are differences in scope of reporting in the GHGRP which is at the facility level and the GHG Inventory which is at the national level. The allocation of emissions across sectors in a national inventory can vary from accounting at the facility-level. As noted in Box 4-1 on pg. 4-7 of <u>the Industrial Processes and Product Use Chapter (Chapter 4)</u>, the GHG Inventory estimates and organizes estimates consistent with national-level reporting as required in international methodological guidelines from the IPCC and reporting guidelines under the UNFCCC. However, with improvements to the Inventory to use GHGRP data for reporting ammonia emissions, there is general consistency across reporting in both programs.

Comment 18: Molar Volume Conversion

First, with regards to Equation 1: Calculation of CO_2 Emissions from NG Feedstock in GHGRP, it is TFI's understanding that EPA should consider a Molar Volume Conversion (MVC) factor of 836 rather than the proposed 849.5 because the calculation fails to allow for actual fluctuations in gas composition that occur among feedstocks.

Response: The GHG Inventory currently uses a MVC of 849.5 in the ammonia calculations to be consistent with the current value in Part 98 Subpart G. However, if the value in Subpart G is updated, the GHG Inventory would update the value as well.

Comment 19: Additional transparency and clarity on information that could be added to the discussion

EPA's approaches to measuring CO2 since GHG reporting began in 2010 have been inconsistent. Here, some uncertainty exists where it appears under the proposal that EPA will calculate and report on the quantity of all CO2 involved in the ammonia manufacturing process. If so, EPA's proposed approach does not accurately reflect direct CO2 emissions from ammonia production because a significant percentage of this CO2 is later consumed on-site for urea production rather than getting emitted to the

atmosphere. that approach is also inconsistent with EPA's recent proposal to modify Subpart G of the GHGRP. On June 21, 2022 at 87 Fed. Reg. 36920, EPA proposes to revise Subpart G to require the reporting of "the GHG emissions that occur directly from the ammonia manufacturing process (*i.e.*, net CO2 process emissions) after subtracting out carbon or CO2 captured and used in other products." To promote consistency and to accurately reflect direct emissions from ammonia production, TFI urges EPA to adopt this same approach for its EPA's annual Inventory of U.S. Greenhouse Gas Emissions and Sinks for the IPPU.

Response: As noted on pg. 4-30 in <u>Chapter 4</u> of the Final Inventory report, only the CO_2 emitted directly to the atmosphere from the synthetic ammonia production process is accounted for in determining emissions from ammonia production. The CO_2 that is captured during the ammonia production process and used to produce urea does not contribute to the CO_2 emission estimates for ammonia production presented in this section. Emissions from industrial urea use are included under the Urea Consumption for Non-Agricultural Purposes category (see page 4-35). The GHG Inventory uses the GHGRP data for total emissions and also information on urea production to arrive at net emissions from ammonia production reported in the Inventory.

Comment 20: types of plants that might impact fuel and feedstock

TFI notes that U.S. ammonia producers are investing significantly in green and blue decarbonization projects that will impact both fuel and feedstock use. Specifically, producers are investing in carbon capture and sequestration technology to generate low-carbon ammonia through conventional natural gas-based processes, as well as investing in renewable electricity or renewable natural gases such as biomethane or synmethane to produce electrolyzed ammonia. Accordingly, TFI urges EPA to adopt flexibility in its methodologies to account for these industry changes as these projects come online in the years ahead.

Response: EPA notes this feedback.

Comment 21: natural gas feedstock use

At this time, TFI has no input to provide other than to urge EPA to take into account its proposed modifications to Subpart G.

Response: EPA notes this feedback.

Comment 22: alternative approaches to determine ratios for fuel and feedstock use

TFI acknowledges and respects the challenge EPA faces to measure periods in time. However, backcasting emissions to as far back as 1990 does not account for efficiency gains where gas usage per ton of ammonia has decreased. TFI membership additionally reports on differences in the manufacturing process where a facility relying upon steam-driven turbines burns more fuel than does a site utilizing electrical-drive turbines that draw from a grid. Further, some sites may have cogeneration units for the energy with which to drive the turbines. TFI is not currently aware, however, of a more precise approach or of a data set that would more accurately calculate these historic emissions. TFI therefore urges EPA in the narrative to the data report to account for this imprecision in the proposed approach of using current data to gauge historical emissions. As one TFI member noted, "EPA needs to be careful in 'over selling' the accuracy of any approach".

Response: EPA notes this feedback in the uncertainty narrative and accounts for likely higher uncertainty associated with data for 1990 as compared to latest inventory year in the quantifying the uncertainty in the Ammonia Production section of the Inventory.

Comment 23: different time periods for feedstock use and fuel data

The proposed approach uses 2010-2014 data on feedstock use and 2011-2015 data on fuel use to backcast emissions. Alternatively, is there a different time period that would be more representative? In addition to efficiency gains and variations in practices, production fluctuates from one year to the next for reasons involving market demand, level of imports, facility maintenance schedules, etc. Further, ongoing increases in shale gas and ethane usage for feedstock, as opposed to relying on natural gas, impacts ammonia production related GHG emissions. While again TFI is not aware of more precise ways to calculate feedstock and fuel usage, TFI does reiterate its suggestion that EPA provide narrative for this imprecision arising out of using current data to gauge historical emissions.

Response: EPA notes this feedback and accounts for it under Uncertainty in the Ammonia Production section of the Inventory discussed on pg. 4-33 of <u>the Industrial Processes and Product Use Chapter</u> (Chapter 4) of the Final Inventory report.

Comment 24: ammonia production information

The Inventory currently uses a mix of sources for ammonia production information (e.g., ACC, Census, etc.). Is other data for ammonia production available? Are you aware of other data sources that could be used?

TFI notes that data submitted by ammonia producers under the Toxic Substances Control Act (TSCA) Chemical Data Reporting (CDR) program could include pertinent information. Similarly, the International Fertilizer Association has gathered benchmarking data that could be helpful.

Response: EPA notes this feedback.

Comment 25: fuel use data for ammonia production

Ammonia fuel use is based on combustion data from facilities that report under subpart G of GHGRP. Those facilities are not specific to ammonia production, and fuel use and combustion emissions include other operations. Is it reasonable to include fuel use data for ammonia production based on this data since it is not specific to ammonia production?

TFI is uncertain about the intent of this question. EPA references Subpart G, which contemplates ammonia manufacturing. But then EPA proceeds to discuss combustion emissions from facilities that are not necessarily involving ammonia production. In which case, EPA may have intended to reference Subpart C, which contemplates general stationary fuel combustion sources.

TFI questions whether utilizing combustion data from facilities reporting under Subpart G accurately reflects fuel use data for ammonia production because that data includes combustion emissions from sources unrelated to ammonia fuel use, including from boilers and other assets involved in operations that are distinct from ammonia production. Utilizing that data set would overestimate, perhaps significantly, the quantity of fuel-related emissions in ammonia production. Similarly, relying on Subpart C "common pipe" data would aggregate fuel consumption across a range of activities over and above ammonia production. Subpart C also fails to account for differences in steam balances within production units, utilization of steam- and electrically driven turbines, and a host of design considerations.

Given lack of specific ammonia only production fuel use and given other industrial sectors mostly report fuel use under the energy chapter, should we just keep current approach of separating feedstock and fuel use data for ammonia in the Inventory even if this does not specifically match IPCC guidelines? For reasons stated throughout this document in the hope of avoiding counting activities that are not ammonia-based, TFI supports continuing to separate feedstock and fuel usage in an effort.

Response: EPA notes and appreciates this feedback.

Comment 26: ammonia production data

GHGRP reporting is based on facilities that emit GHG emissions; the brine electrolysis ammonia process does not emit CO₂ emissions. Therefore, ammonia production data reported under GHGRP might be lower than overall ammonia production. Are there other production processes used to produce ammonia that do not produce process-based CO₂ emissions, which might explain the differences in ammonia production data starting in 2018? TFI does not have market or investment projections to rely upon, but TFI presumes that increases in green and blue ammonia production will grow rapidly due to tax incentives in the Inflation Reduction Act.

Other non-standard operations such as startups, shutdowns, or malfunctions, may cause facilities to not produce as much ammonia but still have CO₂ emissions. Is there information available on the occurrence of these instances?

TFI does not have information to provide because competitors across the industry do not share it.

Response: EPA notes this feedback.

Comment 27: urea production

EPA is not proposing any changes to the existing methodology for ammonia production from petroleum coke or the reduction in CO_2 associated with urea production. Are there areas where those calculations could be updated as well? Are there other sources of information on those components that could be considered?

As indicated elsewhere, fertilizer production is unique because not all generated CO2 gets emitted. The CO2 can be used to produce other products (e.g., urea or UAN) or sold to other consumers (e.g., beverage industry, freeze dried food production, etc.). Even just calculating the amount of CO2 consumed in urea-based products and then subtracting that from the calculation of a site's direct emissions would be helpful; however, doing so, would require the assurance of ongoing confidential business information protection.

Response: EPA notes this feedback.

Chapter 5. Agriculture

Comment 1: Question on clarity and transparency of the agriculture chapter.

You do break dairy into lactating vs heifer classes. How are you accounting for the dry period? I can't tell from the information.

Response: The <u>Annex 3.10</u> provides information about the calculations used in the CEFM. Dry periods are implicitly covered under maintenance energy required (with the animal is lactating or not) coefficient and associated equations.

Comment 2: Enteric Fermentation and Nitrogen Excretion methods; Newer equations for volatile solids excretion for lactating cattle

In the newest version of the USDA GHG methodologies guidelines (which hopefully will be out soon) there are new equations for estimating enteric CH₄ emissions from lactating and dry cows as well as heifers. There are also updated N excretion equations for most animal classes, these would likely be an improvement over the methods/values used from more of the outdated references. These are all published in the literature and if you are interested, I can provide them to you if you have not seen the chapter yet. We also included either new equations or Ym modifiers for some of the enteric methane mitigation strategies.

I also think there are some newer equations that could be used to estimate VS excretion for lactating cattle, not sure if you are using these, it does not look like it. (Appuhamy et al. https://doi.org/10.3168/jds.2017-12813).

Response: EPA is aware of the ongoing updates to USDA's methods report and will monitor its publication. EPA is investigating updated cattle diet data. Both Nex and VS for lactating cattle is currently handled in the CEFM and reported to the manure management team. As noted in the Planned Improvements section of <u>Chapter 5.2</u>, on pg. 5-20 of the Final Inventory report, EPA is interested in comparing and updating the VS and Nex data as appropriate.

Comment 4: 20-year data gap for manure waste management storage systems; Size class distributions for MMS estimates

It is unfortunate the WMS usage is estimated from information that is 20+ years old, although I understand this is one of the largest data gaps that we have. I can only spot check based on my personal experience, but I feel it is inaccurate for Idaho and that may be the case for other states. If every lactating cow in ID was housed in a freestall/mechanically ventilated barn then you might have 50% of the manure handled as a liquid in a lagoon. The majority of our dairies are still open lots and even when the lactating cows are in barns, the dry cows and replacement animals are on lots (50% of the total cattle population).

Also, the size class distribution is very outdated and not relevant to western dairy production. Our small dairies are 1,000 cows. I know that is an artifact from many years ago. I am not sure if the classes can be revised at some point to be more meaningful for the west.

Response: EPA updated the WMS distribution for dairy cows with 2016 regional data with operation sizes provided by USDA and state averages to avoid disclosing any sensitive information. Idaho was grouped with Western states which could have skewed the state-level data. EPA may review and consider approaches to revise the operational breakout.

Comment 6: Assessment of applicability of new information for maximum methane producing capacity

I do have some interesting information related to the manure methane potential (Bo). I finished one study that surveyed 12 farms at two times of the year measuring Bo on fresh manure (right out of the cow) from lactating, dry and heifers and we also collected feed and analyzed that for a variety of characteristics that I thought would affect Bo. I was expecting the Bo to be a lot higher as we see these large discrepancies between methane emissions from lagoons measured on farm vs estimated using the EPA method. The average Bo was 0.23 for lactating cows and 0.16 for dry cows and heifers. But these numbers are highly dependent on the inoculum that is used in the digestion. For one sample the range was 0.17 to 0.30, which is large. It looks like I can do a reasonable job of predicting Bo based on a few diet characteristics. Since your CEFM model has a lot of feed data, that might be something that could be done in the future. We are doing a follow up study where we are looking at how manure handling is affecting Bo. Below is an example from one farm. The Bo from fresh manure was 0.24, then we collected manure going into the primary and secondary separation and the resulting solid and liquid fractions. By the time the manure reached the system "inlet" the Bo was 0.281, the Bo of the subsequent liquid fractions increased to 0.390 and 0.379 with 2 stage separation. So, the liquid going into the lagoon had a much greater Bo than we would currently be using in the inventory methods, which would explain many of the discrepancies we see in on-farm vs estimated emissions. I am happy to share what we have so far if you are interested in any of this data. I am hoping to write up the first manuscript that links diet to Bo in the next month or so. We still have 3 more rounds of sampling to do with the manure handling study so that will not be finished till next fall.

Response: EPA notes the research summary included in the comments and will follow this new work. Currently the B_0 data used for manure management are not developed through assumptions in the CEFM (rather sourced from separate literature), but EPA is interested in learning more about updated national or regional data that could improve the B_0 data. The average B_0 noted from fresh manure is not far off from current dairy cow assumptions, however, if research continues to show that manure handling impacts B_0 that could be a potential improvement to the inventory. As noted in the Planned Improvements section of <u>Chapter 5.2</u>, pg. 5-20 of the Final Inventory report, EPA is interested in updating the current B_0 as representative literature become available.

Comment 7: Use 2019 IPCC Refinement Annex 10A.3 Spreadsheet example for the calculation of a country or regions specific MCF estimation (if not already used). Consider revision of MDP values for Lagoons. Consider model assumption of solid cleanout for all farms in October of every year. In the 2019 IPCC refinement, there is a spreadsheet that can be used to estimate MCFs for liquid storage. If this was not used, this could be a nice improvement.

I have always questioned the MDP number for lagoons, at some point I think this needs to be dropped, especially since there is enough published data out there indicating that on-farm emissions are actually greater than estimated using the methodology. Keeping the MDP makes this discrepancy even larger.

The model assumes a solids cleanout in October of each year. This may not be the case for many farms in the west. There are many farms where the solids are never removed, and the liquid is just pumped out for irrigation. When solids are removed it is somewhat infrequent, unless the farm is not doing any form of separation. Even when there is an earthen settling basin, these basins may only be cleaned out every few years.

Response: EPA notes reviewer's feedback. EPA is considering updating the inventory to the 2019 IPCC refinement methodology as time and resources allow to better reflect the latest science reflected in this guidance. As noted in the Planned Improvements section of <u>Chapter 5.2</u>, pg. 5-20 of the Final Inventory report, EPA does plan to revisit the U.S.-specific MCF methodology in the future.

Comment 8: N volatilized from dry lot systems

Table A-42 volatilization N loss for dry lot seem awfully low.

Response: EPA will review the volatilization N loss during in developing the next annual report.

Comment 9: Manure Management comment on state of industry and revision of assumption that medium to large cattle operations use flush or scrape/slurry systems

I would not consider ID to utilize more liquid based systems to manage and store manure. There have been some larger farms that have converted to freestall and mechanically ventilated barns, however the majority of dairies in the state (same for New Mexico) are still open lot dairies. Dairies in New Mexico do flush the feed alleys which will increase some of the manure handled as a liquid, while in ID many dairies are still just scraping and piling. I am not sure if there are any dairies left in ID that flush, they will either scrape or vacuum and then dump the manure into a reception pit for treatment prior to storage. You state that manure from dairy cows at medium and large operations are managed using either flush systems or scrape/slurry systems (200+ cows define medium and large) That would not be realistic for many western dairies where most small (<2000) cows may be housed in open lots. Even larger dairies (2000 to 8000) may also be housed in open lots. In these cases, the majority of manure would be handled as a solid. In Table A-36: for ID for dairy cow farms you have 3% for dry lot and 26% for solid storage. That seems fairly low.

Response: EPA notes reviewer's feedback. As EPA reviews WMS data to integrate into the inventory, this information could be a logic check to see if the survey data are reflecting on-the-ground knowledge.

Comment 10: Comment on methods ability to effectively capture mitigation efforts effect on emissions, animal feed emission considerations, and impacts of imports and exports of animal products and relevant foreign policy

The IPCC Tier 1 approach uses emission factors based on the average number of animals of different types over the course of a year. The only way to show a decrease in emissions over time is to decrease the number of animals by improving animal production efficiency (fewer animals raised to produce equivalent meat or milk), or by decreasing animal production (fewer animal products produced). For example, if the production efficiency is doubled, half as many animals would be required at any point in time throughout the year. This approach is problematic because the primary way to improve production

efficiency is to dilute maintenance energy or protein through faster growth and higher milk production. However, a higher producing or faster growing ruminant would also have higher energy and protein requirements per animal, a factor not taken into consideration with the Tier 1 emission-factor approach. If the emission factors are not adjusted to the higher production rate, the estimated decrease in emissions due to improved production rate would be overestimated. It also seems to be unwarranted to use emission factors assigned by region or continent when it would be unlikely that the same rates would apply across all countries in each region and decreasing GHG emissions per animal would not be accounted for if only occurring in one country. Management improvements would be difficult to quantify using such an aggregated approach.

The IPCC Tier 2 approach appears to do a better job than the Tier 1 model because not only are the number of animals considered, but also the feed intake of those animals is considered. This model structure should enable a more accurate prediction for the major ruminant sectors in the US. However, it isn't clear that innovations to decrease emissions by using potential drugs (e.g. ionophores), algae, or oils would be reflected in the approach taken. Furthermore, feeding outside of protein requirements could affect N excretion rates, which ultimately could affect N emissions. Since byproducts of ethanol production (e.g. corn gluten feed) are used as supplements to beef feedlot cattle, the protein feeding can be substantially higher than required. The high N feeding would also result in high N in manure and greater losses to the environment. However, this loss should be evaluated against the benefit of producing the alternative fuel ethanol, and the benefit of using a byproduct that may otherwise be a pollutant.

Furthermore, this model does not take into account that there are different GHG emissions from different types of crop production. For example, the decisions made to reduce methane emissions from cattle based on ration might include feeding more concentrates like corn grain, but the emissions from corn grain production may be greater than for forage crop production. In general, one observes very poor efficiency of land and water use for cattle compared to monogastric animals. The way to improve those efficiencies for cattle is to feed them more like monogastric animals. Then the higher energy and protein feeds will be digested and metabolized with higher efficiency. However, the overall system does not necessarily improve because cattle could use land and water resources that are not readily usable by other industries, and that may have lower emissions per area of land. A model to estimate if GHG emissions from ruminant production are improving or not needs to consider cropping and other land use factors as well as herd diet when decisions about the diet affect cropping.

Finally, some ruminant production is imported or exported, and it would be advantageous to accurately estimate the consequences of these imports and exports on both the local and the foreign production. It is likely that each country using different models makes that difficult to do. Furthermore, imports and exports and GHG emissions in foreign countries are affected by US fertilizer, pesticide, and seed imports and exports, and US foreign policy favoring industrial agriculture in foreign countries. Ultimately, US sanctions on 40 countries around the world decrease the efficiencies of agricultural production around the world, the promotion of policies favoring US agribusinesses, and even funding of proxy wars, election interference, and military actions all contribute to GHG emissions, although current models don't account for them. These foreign policy interventions affect US and world ruminant industries and ultimately affect GHG emissions. For example, the recommendation to feed more concentrates to ruminants to decrease enteric methane production encourages destruction of rain forests in Brazil to clear the land for corn or sorghum instead of forage. Adding the cropping and forestry impacts of feeding more concentrate may show that the improvements in enteric methane emissions are negated. Likewise, the political support for US agribusiness expansion into Brazil may have negative

consequences for GHG production. As the US government and large agribusinesses control agricultural production around the world, the US needs to consider the effects of US foreign policy on emissions in those countries.

Response: EPA agrees that Tier 2 shows more variability. EPA estimates emissions from cattle using Tier 2 approaches, capturing more regional variability and US specific data. However, currently, non-cattle (e.g., sheep) are estimated with Tier 1 approaches.

Comment 11: incorporate changes to Section 5 (Agriculture) relating to enhanced-efficiency nitrogen fertilizers, which reduce N2O emissions from nitrogen-fertilized soils

TFI submitted March 16, 2022 comments (attached) on the 1990-2020 Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020 (Docket ID No. EPA-HQ-OAR-2022-0001), advocating for changes to Section 5 (Agriculture) relating to enhanced-efficiency nitrogen fertilizers, which reduce N2O emissions from nitrogen-fertilized soils. As part of its efforts to provide accurate greenhouse gas emissions data, TFI encourages EPA to incorporate into the 1990-2021 Draft Inventory the changes suggested in TFI's March 16th comments.

Response: EPA notes that the recommended text edits were incorporated in the previous <u>1990-2020</u> <u>Inventory report</u>, see page 5-46. EPA is continuing to integrate planned improvements as resources allow.

Chapter 6. LULUCF

Comment 1: Remaining wetlands

ADEQ does not have any additional recommendations on sources of data for the application/consumption of peat.

Response: EPA notes reviewer's feedback.

Comment 2: Flooded Lands Remaining Flooded Lands and Lands Converted to Flooded Lands, data and methods

The data and methods used for Flooded Lands seem appropriate and are clear/easy to understand.

Response: EPA notes reviewer's feedback.

Comment 3: Yard Trimmings and Food Scraps, transparency and other technologies, practices and trends

The state of the industry is accurately described. No new technologies or industries need to be added.

Response: EPA notes reviewer's feedback.

Comment 4: Yard Trimmings and Food Scraps, data sources

ADEQ's Air Division and Solid Waste Division are not aware of any additional data sources available.

Response: EPA notes reviewer's feedback.

Comment 5: Yard Trimmings and Food Scraps, recommendation

It is recommended to discuss with landfills which have a compost diversion program to correlate the decrease in organics entering the landfill.

Response: EPA notes reviewer's feedback.

Comment 6: Representation of US Land Base – Transparency

This section defines different land use categories to establish consistent land classification throughout the country in different years. Data sources were cited and steps were taken to avoid double counting when a land use change from one category to another. Overall, the section is easy to follow and easy to understand.

Response: EPA notes reviewer's feedback.

Comment 7: Representation of US Land Base - Data and methods

Three data sources (NRI, FIA, and NLCD) were utilized to account for the entire land area in the conterminous United States, plus Hawaii and Alaska. The land area was divided into managed and

unmanaged land. These three data sources were chosen because they provide a time series of land-use change data or land management information need for estimating greenhouse gas emissions form land use and land-use change. The alternative data source (Topologically Integrated Geographic Encoding and Referencing) form US Census Bureau does not provide a time series of land-use change data or land management information. Therefore, the best available data source was used which provides confidence in information derived from this data source.

Response: EPA notes reviewer's feedback.

Comment 8: Representation of US Land Base – Recommendations

Transparency: This section defines different land use categories to establish consistent land classification throughout the country in different years. Data sources were cited and steps were taken to avoid double counting when a land use change from one category to another. Overall, the section is easy to follow and easy to understand

Data and Methods: Three data sources (NRI, FIA, and NLCD) were utilized to account for the entire land area in the conterminous United States, plus Hawaii and Alaska. The land area was divided into managed and unmanaged land. These three data sources were chosen because they provide a time series of land-use change data or land management information need for estimating greenhouse gas emissions form land use and land-use change. The alternative data source (Topologically Integrated Geographic Encoding and Referencing) form US Census Bureau does not provide a time series of landuse change data or land management information. Therefore, the best available data source was used which provides confidence in information derived from this data source.

Recommendations: It wasn't clear to me if some unmanaged land can be classified as managed land. If that is the case, are there some steps to make these improvements in the future? Are there some steps that can be taken to account for the 0.4 % difference between the dataset used ((NRI, FIA, and NLCD) and the Topologically Integrated Geographic Encoding and Referencing data? Is the 0.4% difference significant?

Response: The managed land classification process, described in <u>Chapter 6.1</u> of the Final Inventory report, is used consistently with the national datasets for the entire CONUS. The 2006 IPCC Guidelines Volume 4 Chapter 3 provides guidance on the land representation process. Definitions, rounding, and other unique characteristics of the data sources used in the land rep and those noted here there is the possibility for differences in population estimates reported.

Comment 9: Remaining Forest land

Transparency: The overall methodology was clear and transparent. The figures and tables are explained. Sources of information are given.

Data and methods: No recommendations for additional information to be added to aide in providing transparency and clarity.

Recommendations: N/A

Response: EPA notes reviewer's feedback.

Comment 10: Land converted to forest land

Transparency: The categories were presented clearly and easy to understand. The methodology for estimating net carbon stock changes was also very detailed and easy to understand. Data and methods: Methodology and activity data were clear. Uncertainty description provided clarifying information to any remaining questions. Recommendations: N/A

Response: EPA notes reviewer's feedback.

Comment 11: Remaining Wetlands

Transparency: The category and methodology were presented clearly and is easy to understand. Data and Methods: No feedback Recommendations: N/A

Response: EPA notes reviewer's feedback.

Comment 12: Land Converted to Wetlands

Transparency: The category and methodology were presented clearly and is easy to understand. Data and methods: No feedback Recommendations: N/A

Response: EPA notes reviewer's feedback.

Comment 13: Remaining Settlements

Transparency: The overall methodology was clear and transparent. The figures and tables are explained. Sources of information are given. Data and methods: No recommendations for additional information to be added to aide in providing transparency and clarity. Recommendations: N/A

Response: EPA notes reviewer's feedback.

Comment 14: Yard Trimmings and Food Scraps

Transparency: The description of the methodology was clear to understand and apparent to where the data came from.

Data and methods: Improved clarity can be provided as to exactly what the uncertainty is about the composition of the yard waste trimmings are. In the main section, the annual yard compositions seemed to be displayed with clarity.

Recommendations: EPA could consider briefly describing what sources for each section EPA utilizes and why. For example, EPA utilizes the Advancing Sustainable Materials Management: Facts and Figures reports. It may seem obvious as to why you used this source, however, the sources where these reports pull from are not as obvious. A brief description as to what goes into these sources would be helpful. Also, it will help states locate the sources of the information that EPA is looking for.

Response: There may be some confusion over how the paragraph regarding yard trimmings

composition presents uncertainty. As stated, EPA applies an assumption for percent compositions. The underlying uncertainty is attributed to variations in any given year's composition is based on an expert judgement. EPA will update the text to better reflect existing uncertainties when presenting yard trimmings composition.

EPA plans to update the references text in the next annual report to point to the explanation of data sources within the Facts and Figures reports.

EPA has recently updated some of the text regarding trends, which directs readers to the trends and discussions in the Composting and Landfill sections of the Chapter 7 (Waste sector). EPA continues to confirm that data are consistent across sectors.

Chapter 7. Waste

Comment 1: Landfills

The data source in this section are well documented and a considerable effort has been made to update some input data when possible. A special care was taken to make sure no double counting for years with overlapping data source. A continued literature review should be conducted to update some of the default values from IPCC 2006 whenever possible.

Response: The National Inventory is developed using a combination of data inputs and emission factors that are US-specific and within values identified from literature reviews and stakeholder input. Some default emission factors from the IPCC 2006 Guidelines are used in the earlier portion of the Inventory, specifically 1990 to 2004 and EPA believes these default values to be appropriately applied considering the amount of landfill-specific information available during those years. Data used and emission factors applied for emission estimates from 2005 to 2021 stem from facility-specific information reported to the US EPA's Greenhouse Gas Reporting Program. The EPA will continue to review peer-reviewed literature and guidance as they are made available to identify methodological improvements to the National Inventory.

Comment 2: Wastewater Treatment and Discharge: Domestic

The methodology was clear. The sources were apparent, the description of how data used were compiled or sources was not as clear unless directly referring to the referenced documents. Additional data from testing domestic wastewater treatment should be compiled to further understand the impact. ADEQ has created the initiative to test on-site septic systems.

Response: EPA notes the reviewer's feedback and will consider how to improve clarity of how data sources are used to supplement the equations and tables included across <u>Chapter 7.2</u> of the Final Inventory report (e.g., Equation 7-5 and Table 7-10); however, it is not the charge of the Inventory to compile testing data, along with ensuring it is consistent and comparable to derive averages for national estimates.

Comment 3: Wastewater Treatment and Discharge: Industrial

The overall methodology was clear and transparent. The differentiation between the terms and sources for each variable made calculations apparent. Although each variable's source was listed, a further explanation of the source and a brief description of how it was derived would provide completeness in understanding.

Response: EPA will consider this, along with other clarity comments, in future revisions, but generally notes that data citations often explain the basis for factors used within the Inventory to increase clarity within the report text.

Comment 4: Composting

The overall methodology was clear and straight forward. The use of default conditions for facilities across the country, such as waste moisture content, is understandable given the lack of available facility specific data. The literature review EPA recently put together on emission factors should be reviewed and implemented. More detailed data from composting facilities should be attempted to be compiled, with an emphasis placed on waste sub-categories and regional differences in the moisture content of the waste.

Response: EPA will finalize the literature review with analysis of potential improvements to the Inventory methodology as time allows. As noted in Planned Improvements on pg. 7-60 of <u>Chapter 7.3</u> <u>Composting</u>, at present there is a lack of facility-specific data on the management techniques and sum of material composted to enable the use of different emission factors.

Comment 5: Anaerobic Digestion at Biogas Facilities

The methodology was very clear and all estimations made were described with much detail. Continuous monitoring of new data available. The majority of the work in this section was calculated based off a two-year estimation based on the data available alone. This should be updated accordingly as the data becomes more available.

Response: EPA reviews and updates the methodology as each new year of data becomes available. EPA continues to seek out new data sources for this source. Further years of data responses to the AD Survey are expected.

Comment 6: Elaborate on annex

Page 7-10, Lines 13-14. I suggest emphasizing that Annex 3.14 has a detailed description of the method. The current wording doesn't do the annex justice. Some additional detail about the method on page 7-10 or 7-11 would be good. For example, the brief method description on page 7-16 line 32 to page 7-17 line could be moved to page 7-10.

Response: EPA will consider for future updates, no changes to text were implemented in the published report.

Comment 7: Clarifications to correct typographical errors, improve readability and understanding of methods and inputs to methods

• Unit clarification

- Page 7-39, Table 7-25. Is this m³ wastewater per ton of market pulp? The text also refers to wood pulp production. Clarifying this in the header or a footnote would be useful.
- Page 7-64, Line 25, Consider using parenthesis to separate out the units from the text.
- Table references
 - Page 7-52, line 15. Table 7-40 is about composting (which is on page 7-56). The text is apparently referencing only Table 7-39.
- Typographical/Data error
 - Page 7-52, line 20. The 2021 emissions are 23.5, not 3.5, based on the estimate in Table 7-39.
- Clarity/Grammar
 - Page 7-53, line 22. Correction needed: "...updated to reflect revised the same data sources..."
 - Page 7-53, line 30. "productions" should be "production"
 - Page 7-54, line 20. "continued" should be "continue" Page 7-55, line 22. "revised the same" Is one of these words extra?
 - Page 7-57, line 21. "Microsoft FORECAST function". This is an Excel function so the name of the computer program should be included. The actual method being used is least squares linear regression, and the report could refer to that. This comment also applies to Annex page A-90, line 25 and page A-94, line 33, although Excel is mentioned in the Annex.
 - Page 7-58, line 20. "...to enable the incorporate" Should be "Incorporation"
 - Page A-79, Lines 16, 25, and 29, "data" should be "estimates"

Response: EPA has incorporated clarifications/corrections across <u>*Waste Chapter (Chapter 7)*</u> of the *Final Inventory Report. For example, EPA removed the reference to Table 7-40 on page 7-54.*

Comment 8: Unit

Page 7-60, line 34. "The annual amount of biogas produced, standard cubic feet per minute (scfm)" SCFM is a flow rate. An annual amount would be a volume, e.g., cubic feet. Is the value in question an average annual flow rate?

Response: EPA clarified this within the text. From the AD Survey Report (EPA 2021) "biogas production data was collected in, or converted to, standard cubic feet per minute (SCFM), which is the industry standard unit of measurement for biogas." Equation 7-50 on pg. 7-63 of <u>Chapter 7.4 Anerobic</u> <u>Digestion at Biogas Facilities</u> of the Final Inventory report shows how this gas flow value is converted to total biogas production for the year.

Comment 9: Unit

Page 7-62, lines 26-28. As with the previous comment, a total quantity would be reported as a volume, not a flow rate. If the value in question is an average annual flow rate it should be described as such.

Response: EPA clarified this within the text on pg. 7-65 of <u>Chapter 7.4 Anerobic Digestion at Biogas</u> <u>Facilities</u> of the Final Inventory Report.

Comment 10: Food Waste Disposal Factor Change

The change to the food waste disposal factor for industrial landfills prior to this was based on a single reference with a limited dataset. The revised number presented is based on a larger body of data and this is likely to be more accurate than prior estimates. However, it is acknowledged that additional work could be performed to increase or verify the accuracy of this number as more data becomes available. Nonetheless, I have no significant concerns with the estimate at this time.

Response: Methods and assumptions (such as this disposal factor) will be revisited if and when more data on industrial landfilling practices become available.

Comment 11: Landfills

On page 7-5, rows 8-9 describe waste being degraded aerobically until oxygen is depleted. While this is true, a critical point that is not made is the time frame of this aerobic phase is extremely short, with some studies suggesting it is days or weeks upon burial. This time frame is miniscule compared to the decades long residence time of waste in a landfill. The concern is that a reader less familiar with landfills may interpret the aerobic time frame to be much longer, which may lead to erroneous conclusions.

Response: EPA made clarifying edits within the text on pg. 7-4 of <u>Chapter 7.1 Landfills</u> of the Final Inventory Report.

Comment 12: Sources

Page 6, line 26, EPA 2019, Recommend update citation to the latest FF report released in 2020. It won't necessarily affect the range presented (when using the landfill link that notes 1908 landfills in 2009). I did observe that the 2018 F&F data tables (Table 34) use LMOP landfill data to note the number of landfills (Source: U.S. EPA. Landfill Methane Outreach Program (LMOP) Facility-level database. Data represents MSW landfills open July 2019)

Response: The reference was updated.

Comment 13: Landfill

Page 7-6, line 51, It is unclear whether landfill quantities will go up or down.

Response: EPA refined the text on page 7-6 of <u>Chapter 7.1 Landfills</u> of the Final Inventory Report to make clear that impacts are still unknown of coronavirus pandemic on landfill disposal rates.

Comment 14: Land Application

Page 7-13, Box 7-3, Land application is not the only use for compost (e.g., storm water infrastructure is not considered "land application"). Land application is its own pathway, see 2018 Wasted Food Report (EPA, 2020)

Response: EPA made clarifying edits within the text in Box 7-3, see pg. 7-13 of <u>Chapter 7.1 Landfills</u> of the Final Inventory Report.

Comment 15: China influence

"Due to China's recent ban on accepting certain kinds of solid waste by the end of 2017 (WTO 2017), inclusive of some paper and paperboard waste, plastic waste, and other miscellaneous inorganic wastes, there has been a slight increase in the disposal of paper and paperboard and plastic wastes since 2017 (<u>Table 7-6</u>). Future impacts of China's recent waste ban to <u>on</u> the composition of waste disposed in_U.S. landfills are unknown at this time."

Page 21 Box 7-4, Please delete this, we don't know the relationship between China's ban and waste disposal as estimated in the Facts and Figures report.

Response: EPA removed this sentence from the text in Box 7-3 on pg. 7.13 of <u>Chapter 7.1 Landfills</u> of the Final Inventory Report.

Comment 16: Structure/style of report narrative, in particular

- Page 7-2, While it should be obvious what the data source is for statistics provided, would still recommend noting the data source for each graphic
- Page 7-21, Consider proofreading this subsection for text flow, equation flow and variable and unit descriptions. Where a specific calculation involves several subsets of calculations, consider adding structure for clarity and user friendliness. Several specific examples are highlighted in comments below.
- Page 7-60, Consider using parenthesis to separate out the units from the text

Response: EPA also notes different reviewers have expressed differing views on ease of reading and clarity in recent years. EPA will continue to consider further clarifications and revisions to content organization for future versions of this report, and some clarifications were included as noted in response to specific comments within this summary document.

Comment 17: On-site Treatment

Page 7-22, Line 1, Consider talking about on-site treatment upfront, before centralized treatment. The reason is that the discharge section appears to be focused on wastewater discharge, which is associated with centralized treatment.

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 18: Discharge

Page 25, line 9, It'd be helpful to define what all is included under the discharge. The front of this discussion appears to be focused on wastewater discharges to aquatic environments, which are associated with centralized treatment. Further down in the text, however, there is mention of how wastewater treatment and discharges have decreased over time in part due to reduced use of on-site septic systems. It is, therefore, unclear if discharges to soil from septic systems are also captured under "discharge." Alternatively, the part about reduced use of on-site septic systems could be linked to the reduced wastewater (influent) treatment only and not discharge. If latter is the case, consider including a new subheading for the text below so it does not appear relevant for the "discharge" discussion.

Response: The decrease to wastewater treatment and discharge refers to emissions (and is stated as such on pg. 7-22 in the text of <u>Chapter 7.2 Wastewater Treatment and Discharge</u> of the Final Inventory report). This is due to emissions from septic systems being relatively high. This is not due to decreased volume of discharges. EPA will consider updates to subheaders in future versions of this report.

Comment 19: BOD

Page 7-22, line 24, But it must first be confirmed that the water sample is in fact an anaerobic environment? The topic is effluent - waste water discharges – and the dissolved oxygen could vary?

Response: EPA added "In summary" to pg. 7-23 of <u>Chapter 7.2 Wastewater Treatment and Discharge</u> of the Final Inventory report to distinguish that the text the reviewer mentions is not associated with discharges.

Comment 20: Domestic Wastewater Treatment and Discharge

Page 7-22, line 32, It appears that this subsection may need to have its own subheading either way. Otherwise, all of this appears to be relevant for the Discharge discussion.

Response: EPA added a statement about overall emission estimates to help transition the reader on pg. 7-24 of <u>Chapter 7.2 Wastewater Treatment and Discharge</u> of the Final Inventory report.

Comment 21: Word Choice

Page 7-24, line 12, Is "more accurate" the right wording here? It seems that short of finding/changing the source, it might not have been possible to produce these estimates at all. It sounds like the message is that EPA incorporated and transitioned to new data sources in a way that EPA confirmed is appropriate, ensuring both continuity and accuracy.

Response: EPA incorporated changes to remove 'more accurate' and reflect the reviewer's feedback on pg. 7-25. The reviewer's understanding of the approach to incorporating new data sources is correct.

Comment 22: Population Scaling

Page 28, line 6-7, It seems that the US population is here used to scale up the emission factor to the US emissions, and that the percentage is then applied to limit the emissions to the septic system. Consider casting the calculation in a way that conveys the gist of the calculation, rather than listing out the factors.

Response: EPA notes the reviewer's feedback on enhancing clarity and will consider it for future versions of the Inventory report. See also response to comment 16 above.

Comment 23: Table Format

Page 7-25 to 7-26, Table 7-10, EFseptic units, Consider revising to the format that makes it clear where the main fraction line is, e.g., g CH4/(person x day). This suggestion applies to units in other tables as well.

Response: EPA did not update this as units are already clearly noted as per capita per day.

Comment 24: BOD Page 7-26, Line 4, According to the definition above, shouldn't this be "consumed" or "needed" instead of "produced?" BOD is not the measure of oxygen being produced, but is a measure of oxygen being expended to decompose organics? Consider clarifying either upfront or here.

Response: EPA updated this to TOW to avoid this potential confusion on pg. 7-27 of <u>Chapter 7.2</u> <u>Wastewater Treatment and Discharge</u> of the Final Inventory report.

Comment 25: Equation

Page 7-26, Equation 7-6, Consider using "%garbage disposal" instead of just "%disposal". For us who work on waste, this looks too much like a landfilling rate, and (1-%disposal) looks too much like a recycling rate.

Response: EPA updated the terminology in Equation 7-6 for this equation to %kitchen disposal to reduce potential confusion. See pg. 7-27 of <u>Chapter 7.2 Wastewater Treatment and Discharge</u> of the <i>Final Inventory report.

Comment 26: Equation

Page 7-26 to 7-27, Equation 7-7, Shouldn't another conversion factor be incorporated for conversion from kg to Gg in this equation?

Response: EPA added the conversion factor to Equation 7-7 enhance transparency. See pgs. 7-27 to 7-28 of <u>Chapter 7.2 Wastewater Treatment and Discharge</u> of the Final Inventory report.

Comment 27: Equation

Page 7-27, Lines 3-19, It would be helpful and more reader friendly to reference equation(s) below as they pertain to approaches being discussed here. Otherwise, this language becomes hard to follow, and below, the context around equations gets lost.

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 28: Equation

Page 7-27, Equation 7-8, ? Nothing below connects in an obvious way to this equation.

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 29: Table 7-13

Page 7-28, Table 7-13, TOW variable description, if this is per capita, is there also an adjustment for population size? How is that captured in the equation above? Suggest double checking equations, tables and units throughout to make sure conversion factors and population adjustments are consistently included, where needed.

Page 7-28, Table 7-13, TOW Units, if this variable is per capita, shouldn't this unit then be Gg BOD/(year x person)?

Response: EPA updated the unit label for TOW to reflect the "/capita" in Table 7-13 on pg. 7-29 of <u>*Chapter 7.2 Wastewater Treatment and Discharge*</u> of the Final Inventory report. See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 30: Equation 7-11

Page 7-28, Equation 7-11, Equations are hard to follow since the framework/context/stepwise approach doesn't come out clearly. Consider providing a structure and a hierarchy, through subheadings and descriptions so that relationships are clearer. For example, this part and sequence of equations pertains to centrally treated aerobic systems other than constructed wetlands, while the next one pertains to constructed wetlands only, and the next to constructed wetlands used as tertiary systems. Consider including a subheading for each. Consider also emphasizing more strongly upfront that those three are the key pieces needed to determine emissions from centralized aerobic systems. Lastly, in this set of equations specifically, it appears that the main equation is 7-11 and that the two above provide factors for inclusion in this equation. Consider explaining that relationship more clearly. E.g., start with equation 7-11 and then introduce the other two as equations that are providing the factors needed for equation 7-11. Note also that the approach of moving between different levels of equations, e.g., from the highest to the lowest level equations, may currently be inconsistent between calculations. Consider checking throughout.

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 31: Anaerobic Systems

Page 7-30, Line 5, Consider comments above, as applicable

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 32: Equation 7-17

Page 7-32, Equation 7-17, Consider moving this equation to the bottom, so that equation 7-16 is the topmost and provides context, equations 7-18 and 7-19 follow and provide information about how factors in equation 7-16 are calculated, and equation 7-17 is last and then provides information about how the main factor in equations 7-18 and 7-19 is calculated. Basically, consider starting with the highest-level equation and then moving down one level of detail for equations that are included next.

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 33: Table 7-19 Note

Page 7-32, Table 7-19 Note, the scale of CH4 emission values is small, so consider maybe including the second decimal point for the emissions. E.g., because the CH4 emissions for the bottom three industries all round down/up to the same number, while the % of industrial wastewater CH4 is different in each case, the values for CH4 emissions are not as representative and meaningful as they could be.

Response: The data are formatted consistent with the style for the Inventory report. EPA will consider if an exception is helpful for future versions of the Inventory report.

Comment 34: Equation 7-20

Page 7-34, Line 1 I think that this format of providing a clear description followed by the equation is user friendly and helpful.

Response: EPA notes the reviewer's feedback. See also response to comment 16 for the Waste Chapter (Chapter 7).

Comment 35: Equation 7-20

Page 7-34, Line 6, For inventory year? Question applies throughout.

Response: EPA did not update this as the year unit is already clearly noted with the variable.

Comment 36: Equation Parameters

Page 7-34, Line 25-26, Which equation(s) are those parameters used in? Is wastewater generated the same as Wastewater outflow?

Response: Yes, outflow and generated are the same in this case. The average wastewater outflow and organics loading data in Table 7-21 are used in Equation's 7-20 to-7-24 as listed. See also response to comment 16 for the Waste Chapter (Chapter 7).

Comment 37: Saerobic

Page 7-34, Line 38, If this is the same variable as Si then it makes sense for it to be expressed the same way throughout.

Page 7-35, Line 8, Consider increasing consistency between variable names to increase clarity and decrease confusion. Based on other names, it seems that this variable should be Si (as it pertains to several industries).

Response: For this particular example, that is not appropriate. S_i is meant to show the equation applies to multiple industries (where i is a given industry). The S_{aerobic} in Equation 7-23 is applicable to pulp and paper and therefore has a separate name. However, EPA notes the reviewer's general feedback to ensure consistency in the approach to variable labels across Chapter 7.2 Wastewater Treatment. See also response to comment 16 for the Waste Chapter (Chapter 7).

Comment 39: Equation 7-24

Page 7-35, Line 22, Doublecheck the variable name/description. Above the description for W is wastewater generated. If the two are the same, then the description should be consistent. If the two are different then the variable names should be different.

Response: EPA updated the variable name from generated to outflow though they are synonymous in this case.

Comment 40: Emissions Factor

Page 7-35, Line 23-34, Consider moving this up since emission factors are relevant only for equation 7-20, which is on the previous page. Consider proofreading for flow.

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 41: Equation 7-25

Page 7-37, Line 12, Up above, even when units are per year, these same words are not used in variable descriptions. Consider double checking all variable descriptions for description completeness and consistency.

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 42: Domestic Wastewater N₂O Emission Estimate

Page 7-42, Line 1, Consider whether/how the detail-oriented comments made in the subsection on CH4 emission apply here as well.

Response: See response to comment 16 for the Waste Chapter (Chapter 7).

Comment 43: Clarification

Page 7-54, Line 21, Implement what?

Response: EPA clarified this that the "what" EPA is implementing "improvements" on pg. 7-56 of <u>*Chapter 7.2 Wastewater Treatment and Discharge*</u> of the Final Inventory report.

Comment 44: Clarification

Page 7-55, Line 36, is food / beverage manufacturing/processing composting included?

Response: The currently used estimates of waste composted per year does not include food and beverage manufacturing waste.

Comment 45: Clarification

Page 7-55, Line 45-46, Does this intend to say "an increase in"? If not, this statement doesn't seem to connect to why there's been in increase

Response: EPA made edits in the text to clarify. See pg. 7-58 of <u>Chapter 7.3 Composting</u> of the Final Inventory report.

Comment 46: Data

Page 7-57, Line 12, EPA's 2018 Wasted Food Report includes estimates for the amount of food waste

composted by food and beverage manufacturers and processors. See page 40 – the estimate is 862,707 tons.

Response: EPA will review this data source for possible inclusion in future inventories.

Comment 47: Digestate word choice

Page 7-59, Line 4, "Soil Amendments" Digestate may be a more accurate term. Digestate can be used in land applications, as well as applications that do not affect soil or crops, as in for example, animal bedding. Soil amendment may, therefore, not be a sufficiently inclusive of a term. Page 7-63, Line 11, "Digested sludge" Digestate is a better term here, too.

Response: EPA reflected these edits in the text on pg. 7-61 of <u>Chapter 7.4 Anerobic Digestion at Biogas</u> <u>Facilities</u> of the Final Inventory report.

Comment 48: Co-digestion

Page 7-59, Line 21-23, Co-digestion also occurs at wastewater treatment plants – a combination of wastewater solids and food waste or other feedstock

Response: EPA made edits in the text.

Comment 49: Standalone digesters

Page 7-59, Line 31, These can be subdivided into industry-dedicated digesters that solely process waste from one industry/industrial facility (often food or bev manufacturing/processing), or multi-source, which process feedstocks from various sources (municipal food scraps, manure, food processing wastes, etc.)

Response: EPA made edits in the text on pg. 7-62 of <u>Chapter 7.4 Anerobic Digestion at Biogas Facilities</u> of the Final Inventory report.

Comment 50: Chapter 5

Page 7-59, Line 41, Consider whether any of the comments related to AD facilities in this chapter 7 then apply to chapter 5 as well.

Response: EPA will review for cross-chapter consistency.

Comment 51: Timeseries

Page 7-59, Line 42, Further text in this paragraph suggests that this report provides emission estimates for the period between 1990 and 2018, by extrapolating the 2015-2018 data to the 1990-2014 timeframe. Nothing in the paragraph's text mentions years 2019-2021, which leaves some room for confusion. Please revise for clarity.

Response: EPA will review for clarity. Because there is only data from AD Surveys for years 2015 to 2018, data is extrapolated for both 1990-2015 and 2019-present. The uncertainty for the emission estimates from this source reflects the limitations of this method.

Comment 52: Timeseries

Page 7-59, Line 46, According to the language and equations below, the 2017 and 2018 data are not used for estimates between 1990 and 2014. Please consider editing this paragraph to increase clarity.

Response: Amount of waste digested is limited to data from years 2017 to 2018. EPA will review for clarity and explore using the data from all years with survey results.

Comment 54: Equation 7-49

Page 7-60, Line 26, Since it is stated above that methane emissions from anaerobic digestion depend on the type of waste managed, it may be helpful to also explain why all organic wastes (including e.g., food waste and manure) are captured together instead of individually. Unless... organic waste is here used in an overarching way while the mass is meant to be specific to particular streams (e.g., food waste or manure), but if that were the case, it would need to be stated.

Response: EPA will consider clarifications to the text for future versions of the Inventory report.

Comment 55: Equation 7-49

Page 7-60, Line 28, Consider clarifying if the emission factor is the same for all organic waste or if it changes depending on the waste subtype (e.g., food and non-food waste)

Response: EPA will consider clarifications to the text for future versions of the Inventory report.

Comment 56: Wastewater terminology

Page 7-61, Line 14, "Water resource recover facilities (WRRF) This term is not used in the section on wastewater treatment. Consider standardizing or defining terms used across sections (i.e., WRRFs, POTW, etc.)

Response: EPA will review for consistency for future versions of the Inventory report.

Comment 57: AD facilities

Page 7-61, Lines 26-29, If there is a difference between item 2) and 3), it may need to be made clearer. I am reading both as "there may be additional stand-alone AD facilities that process food waste."

Response: EPA will consider clarifications to the text for future versions of the Inventory report.

Comment 58: AD facilities

Page 7-61, Line 29, A fourth caveat: EPA's AD survey does not ask for quantities of manure processed at on-farm co-digesters or wastewater solids processed in WRRF co-digestion systems. Manure and wastewater solids make up the bulk of feedstocks processed by on-farm and WRRF digesters,

respectively. Therefore, the amount of non-food waste processed via AD is much higher than accounted for in survey results. Perhaps this is not important to include here because this section only discusses stand-alone digesters.

Response: This is accounted for in the methodology.

Comment 59: AD facilities

Page 7-61, Lines 32, Recommend clarifying again that this section only considers stand-alone digesters, since the AD reports discussed immediately above include other types of digesters as well.

Response: EPA will consider clarifications to the text for future versions of the Inventory report.

Comment 60: Equation 7-51

Page 7-61, Lines 39, Should this equation be revised to incorporate also the 2017 and 2018 data? If not, could you explain why not, and how the 2017 and 2018 data are then used, considering that they are cited above?

Response: For the first year of using the survey data to develop waste processed averages across the timeseries, EPA used masked survey responses at the facility level that were provided by the EPA office that conducts the survey. These values are not provided in the published survey results, instead they are published in the aggregate. Due to time and resource constraints, EPA has not looked at the facility level results since that initial year. EPA will work with the survey developers to provide this information again to the inventory team for future updates to this methodology.

Comment 61: Equation 7-51

Page 7-61, Lines 42, Please see comment above about possibly explaining why estimating methane emissions from food and non-food waste sources jointly and in the same way, e.g., by using the same emission factor, makes sense.

Response: EPA will consider clarifications to the text for future versions of the Inventory. Based on limitations of data available, only one emission factor is used in the methodology at present.

Comment 62: Organization timeseries

Page 7-62, Lines 5-13, This text answers some of my questions above about how data from different years are used and for which years' estimates, so consider using it to augment the text above and avoid confusion upfront. It'd also be of value to add more on why only the 2015 and 2016 data are used to produce estimates for the historic years as well as, why they are used preferentially over the 2017 and 2018 data.

Response: EPA will consider clarifications to the text for future versions of the Inventory report.

Comment 63: Word clarification

Page 7-62, Line 12, "average", Weighted average? Or was the number of facilities the same since one survey covered both years and therefore, the weighted average doesn't make sense? Again, please

provide a bit more clarity as well as explain the rationale for why 2 years of data are being used to forecast the future amounts. I understand that the assumption would be that the same facilities would operate in the next couple of years, but why take an average of the data for those facilities over 2 years and bring the amount of waste down vs. moving forward with the most recent year and a higher amount, considering how the quantity of waste generally grows year over year and that the quantity of feedstock for AD is likely to increase, too; also, the 2018 data demonstrate that the facilities have the capacity to process more than what was processed in 2017.

Response: EPA will consider clarifications to the text and explore using the data of amount of waste digested from all years with survey results for future versions of the Inventory report.

Comment 64: Uncertainty Takeaway 2

Page 7-63, Lines 18-22, Please clarify the takeaway message here. The text points to the deficiency in the 2015 and 2016 data that carries over into the estimates for period from 1990 to 2014, but this deficiency does not exist in the 2017 and 2018 data. However, is the other takeaway that the 2017 and 2018 data are still not as accurate as they could be, because liquid wastes were not provided in tonnages and had to be converted? Or is the message: there is an underestimation for 1990 to 2016 but the 2017 and 2018 estimates are fine?

Response: EPA is reviewing uncertainty, including the qualitative description, as part of ongoing improvement efforts, so will consider further clarifications to the text in future versions of the Inventory report as part of those updates. EPA will reach out to the reviewer to clarify the scope and findings from the uncertainty analysis.

Comment 65: Stand Alone AD

Page 7-63, Lines 29, "biogas facilities, recommend specifying again that these are only at stand-alone digesters, since biogas facilities can also exist alongside AD systems at WRRFs or on farms

Response: EPA made edits to the text to reflect reviewer's feedback on pg. 7-66 <u>Chapter 7.4 Anerobic</u> <u>Digestion at Biogas Facilities</u> in the Final Inventory report.

Comment 66: Wet Waste

Are you aware of the 2020 national wet waste inventory done by PNNL and NREL? https://data.mendeley.com/datasets/f4dxm3mb94/1 See also the associated dataset that models COD in wastewater facilities: https://data.mendeley.com/datasets/wf64vzcg58/2 and the peer reviewed publication that resulted from it: https://doi.org/10.1016/j.jenvman.2020.110852

Response: EPA plans to review resources provided and determine if there are viable data to update activity data or methods within the inventory.

Comment 67: Biosolids

There is a newly updated version of the Biosolids Emissions Assessment Model (BEAM) this year. This is currently the global gold standard for this topic area. If it is possible to mention the tool in the text or as a reference, that would be helpful to facility operators, engineers, or researchers looking for tools to

assess emissions at the facility level. It may also help you refine the error bars. The tool is available at: https://www.biosolidsghgs.org/ An article about the tool is attached, you may be interested in the chart at the bottom of the 2nd page showing the tool's GHG estimates for 7 different biosolids management processes at a large wastewater treatment facility.

Response: EPA notes this is a facility-level tool and will assess applicability to inform national estimates of emissions from wastewater treatment and discharge. While EPA plans to review the source provided, additions to mention a model currently not used in the methods is not typical, and is not a charge, for the Inventory.

Comment 68: Sludge Production

see the newly published report of estimates on sludge production and disposal for the Northeast attached. A separate but related effort known as the National Biosolids Data Project is underway to quantify sludge production nationally and results should be available soon. This should replace the 2004 Beecher citation

Response: EPA did update sludge based on the new NEBRA data, though used a national source rather than only Northeast data.

Comment 69: PFAS

Increasing concerns about PFAS have the potential to dramatically reshape the overall waste sector, with a particular impact on wastewater treatment and biosolids/sludge. It is possible that over the next decade we will see a large shift to high temperature/high pressure processes as facilities attempt to destroy the residual amounts of PFAS present in these sludges. Already, the state of Maine has banned land application of sludges, shutting off one of the 3 traditional pathways of sludge disposal (incineration, landfill, and land application), and it appears that other states may soon make similar decisions. In Maine, it appears that this means a wholesale shift to landfilling of wet sludges. While this is all in flux and the impacts on GHG are impossible to predict with any accuracy, there *will* be industry-wide impacts in the next few years that require you to shift some of your methodologies and assumptions about wastewater treatment and sludge disposal.

Response: As EPA continues investigations to determine updated national wastewater treatment sources, it will be cognizant of this trend to make sure expected changes are reflected in the Inventory.

Comment 70: Sludge

Page 7-3, lines 21-22: "EPA is not able to estimate emissions associated with sludge generated from the treatment of industrial wastewater or the amount of CH4 flared at composting sites "For industrial sludges, I am attaching a paper from DOE that may get you started. Suggest you contact Anelia Milbrandt, National Renewable Energy Laboratory, and/or Mark Philbrick at DOE as they were two of the leads on producing this paper. See Section 1.1, targeted feedstocks, for a list of industrial feedstocks (both in the table and footnote 1) that you could consider trying to assess, and Chapter 1 references for a list of sources that may provide you with estimates on quantities produced. It may be something that has to wait until next year's report but at least this is a place to get started. I am not aware of any composting sites that flare CH4. In general, composting is aerobic, or at least intended to be aerobic, and compost facility design does not include gas collection systems and flares. However, this is based on

individual site visits and general industry knowledge, and I am not a compost systems engineer so I may be missing something. I suggest you check with Nora Goldstein at Biocycle to see if she is aware of any significant CH4 collection and flaring at composting sites.

Response: EPA plans to review the studies and resources shared by the reviewer for industrial (not composting for wastewater treatment) and determine if there are viable data to update activity data or methods within the inventory. EPA will follow up with the additional experts mentioned as applicable and needed.

Comment 71: Sludge

Table 7-9, domestic wastewater CH4 emissions: It may be time to revisit some of the underlying assumptions for these calculations. This recent publication comes up with an estimate of about 2x as much CH4 from septic systems as we do (comparing Table 2 of the paper to Table 7-9): https://doi.org/10.1016/j.envres.2022.113468

Response: EPA briefly reviewed the literature and associated table noted by the reviewer. While the data are promising, it does not appear the data are necessarily US-specific. Further review is required to assess whether updates to the current methodology are appropriate and would reflect sound science.

Comment 72: Landfills – MSW assumption

In the RTI memo, it states "EPA's 2018 Wasted Food Report₉, which are the detailed estimates using the EPA's Scoping Memo methodology, estimates 3.3% (1.3 million tons landfilled to 39.8 million tons generated) of food waste from the industrial sector (food and beverage manufacturers) is landfilled; however, we believe this excess food is assumed to go to MSW versus industrial waste landfills" (page 4). Why is the assumption that this waste is assumed to go to MSW landfills versus industrial ones? The NAICS codes in scope for the industrial sector in this report are 311 and 3121 (excluding 311111, 311119, 312112, and 312113). Is it due to an assumption that waste from retail bakeries (NAICS code 311811) would go to MSW landfills? Based on my understanding of these establishments, and the NAICS code description, I am not sure if that's a fair assumption. Would be interested in more information to support that claim.

Response: The EPA 2018 Wasted Food Report was built off of work from the EPA Facts and Figures, which only considers waste managed by the traditional MSW system.

Comment 73: Landfills – comparison of EPA's excess foods opportunity map with inventory estimates Also, on page 5 of the RTI memo, it states "On the other hand, the Inventory estimates are relatively close to the lower end of EPA's Excess Food Opportunities Map data (2.5 MMT to 8.1 MMT) with the understanding that not all of this food waste is landfilled; **we believe the higher end estimate likely consists of excess goods being disposed in MSW landfills versus industrial waste landfills**". The generation factors used for the low- and high-end estimates contained in the Map's data set for food and beverage manufacturers and processors are both based on FWRA/BSR studies and are revenuebased. They have nothing to do with any assumptions regarding final destination for this sector's waste. The Map does not make any assumptions about how waste is managed or where it ends up and both low- and high-end estimates are only generation estimates. See Table 2 of the <u>technical methodology</u>. So the assumption in the last part of that sentence is incorrect and should be deleted.

Response: EPA will remove this from future consideration when developing the food waste disposal factor.

Comment 74: Composting - data

We have some data for PR and Guam; we will share our latest national composting data set that has recently been updated for inclusion in the Excess Food Opportunities Map, Version 3.

Response: EPA Inventory staff will follow up with the reviewer on available data noted.

Comment 75: Anaerobic digestion at biogas facilities – appropriateness of weighted average

To obtain input on the appropriateness of using the weighted average (or the median), it would be best to consult a statistician. Sources suggest that this decision can be based on a histogram. If the data distribution follows a bell curve, then the weighted average and median values should be similar and either of the two can be appropriate to use in linear regression. If the distribution curve shows more than one peak, it is unclear that either value is appropriate.

Response: EPA has used the only available data for this source and takes the completeness of the data into account when developing the uncertainties.

Comment 76: Anaerobic digestion at biogas facilities – facility-specific data sources

American Biogas Council (ABC) maintains a database of renewable natural gas (RNG) projects, with some stand-alone food waste AD facilities dating back to 2010. ABC may have data from prior years, but the industry is still young. Additionally, state environment agencies with active industrial or "merchant" anaerobic digesters – OH, WI, CA, MA, NY – may have data from earlier years. EPA has a list of AD facilities that we develop for use in our Excess Food Opportunities Map. We can share the most recent data set, which is in the process of being added to the map for Version 3. However, we do not have additional data on the amount of waste processed per facility in this data set.

Response: EPA will evaluate feasibility of including this data in the future.

Comment 77: Landfills

Transparency and clarity: The data source in this section are well documented and a considerable effort has been made to update some input data when possible. A special care was taken to make sure no double counting for years with overlapping data source.

Completeness and accuracy: A continued literature review should be conducted to update some of the default values from IPCC 2006 whenever possible.

Response: As part of continuous improvement efforts, EPA conducts regular literature reviews. In addition, the Greenhouse Gas Reporting Program has a proposed rule which would increase the information reported annually on emissions from MSW landfills. This could improve our understanding of conditions and activities at landfills in the United States and therefore provide data to update these default values in future versions of the inventory report.

Comment 78: Landfills - Revision of food waste disposal factor for industrial landfills

I think changing the food waste disposal factor from 4.86% to 6% for years 2010 to current year was a necessary change since the 4.86% factor was based on outdated data from 1985. It's possible that population growth, change in cost of living, and change in cultural behavior has affected food waste over the years. It would be valuable to assess how much the food waste factor vary from one year to another to see if the use of a constant factor is appropriate. However, as noted in the memo, we do recognize the "lack of transparency and large difference in waste disposal data for food and beverage sector".

Response: It is not possible at this time to use a year by year food waste disposal factor for industrial food and beverage processors.

Comment 79: Wastewater treatment and discharge

Additional industries: The chapter includes the industrial sources that I am aware of. In addition, I am unaware of any national-level or state-level data for the mentioned industries. Methodology discussion improvements: The methodologies described in this section are clear and provide enough information for the reader to follow. Sources of the data utilized were provided. Additionally, the data was collected from credible sources and justification for using the various sources was also provided. Further discussion of the factors referenced and how they were derived would assist in understanding their origins.

Response: As part of ongoing efforts to improve transparency and clarity of methodological discussions, EPA will consider this, along with other clarity comments, in future revisions, but generally notes that data citations often explain the basis for factors used within the Inventory to increase clarity within the report text.

Comment 80: Domestic Wastewater Treatment & Discharge

National level data, types of wastewater treatment systems: The national level data on the types of wastewater treatment systems in operation appears to be representative. Where data was lacking linear interpolation was used to complete the data set.

Current and accurately described: The description provided for the state of domestic wastewater treatment is current and accurate to the best of my knowledge.

National level data, biogas generation and recovery: Further discussion on biogas generation and recovery operations within the section would assist with understanding the basis of this question. BOD and N discharge estimation: If there is a way to compare variability, and the data is consistent enough, then BOD and N discharged in effluent should be estimated using the limited data from ICIS-NPDES. Although there is limited data, this method relies on result-based data. Also given that in the planned improvements section there is discuss about improving this method, the data will only become representative.

Non-consumed protein factor: The default IPCC non-consumed protein factor for centralized treatment seems appropriate in this case. Unaware of any sources to create a U.S. specific factor.

Additional sources for N content of sludge: No additional sources.

Volume discharged: No additional sources.

Response: For biogas generation and recovery, EPA did not make additions based on this comment as it's unclear what the reviewer needs to further interpret the emissions from biogas generation and

anaerobic sludge digester methodology and discussion. For BOD and N, EPA notes the reviewer's feedback and will continue to investigate these data.

Comment 81: Industrial Wastewater Treatment & Discharge

Measurement data for N_2O from industrial wastewater: Industrial wastewater treatment systems are commonly required to have continuous flow monitoring. Additionally, in AZ nitrates/total nitrogen are recommended to test for in effluent but are not required. Requiring industrial facilities and funneling the information from the city to state to national dataset could give you the best monthly data.

Changes over timeseries: No additional sources are known for the industries included. Arizona has the Agribusiness and Water Council which could assist in providing wastewater data.

National or state level production data: As far as ADEQ is aware, the USDA NASS would provide the most complete basis.

Current and accurately described: The industrial wastewater treatment technologies are current and accurate.

National level data, biogas generation and recovery: Industrial processes have the tendency to facilitate sulfate reducing bacteria which can compete with the biogas production. Discussion of this or data collected could be added.

Volume discharged: Volume of discharge is best estimated by continuous discharge flow monitoring. Compiling the detailed information from facilities is believed to be the best estimate.

Response: Development of facility-level reporting requirements are beyond the scope of the national Inventory. For available data, EPA would need to investigate what is available and published by states, but also have comparable and consistent data from industrial facilities to inform/improve national-level estimates. For volume discharged, EPA notes the reviewer's perspective. Similar to the notes above, while EPA agrees this type of information should be a good basis for data, in order to be useful for national scale estimates, EPA would need to understand the comparability and consistency of the data collected at these levels. For industrial biogas, as EPA investigates industrial operations more, it can review or add clarification along these lines.

EPA notes reviewer's feedback on the additional topics listed under Comment 100.

Comment 86: Composting – Datasets for industrial facilities in specific US territories

ADEQ is unaware of any additional available data sets for industrial composting facilities; though we agree with EPA that more detailed facility specific data is needed.

Response: EPA notes the reviewer's feedback.

Comment 87: Anaerobic digestion

Transparency and clarity: Overall the methodology is very transparent. The process of identifying the number of operational facilities is clear. Assuming, the overestimation of facilities is clearly stated and reviewed that the count itself does not translate to an overestimate of the annual waste. The weighted average being used is more accurate compared to the median. This is mainly due to the extremely limited data, the median found would not be accurate or applicable across different years. Facility specific data sources: The weighted average that was taken for the estimation of total waste digested seems to be an accurate way to calculate with the data available. Specific data sources that could be used to find a more accurate data would be to contact the facility directly, because of the data

being unavailable on other databases already. As well as noting any years they were not in operation and adjusting accordingly. Along with the statements listed in the Planned Improvements section.

Response: EPA appreciates the feedback and does take the limitations of this data source into account when developing the uncertainty for this source's emission estimates.

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: 1990-2021* 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.

- Hilary Moore Arizona Department of Environmental Quality (ADEQ)
- Kevin Nakolan Energy Information Administration (EIA)
- Mike Madsen Hawaii Department of Health
- Chris Barry NJ Department of Environmental Protection
- Thomas Lynch The Fertilizer Institute
- April Leytem USDA-ARS
- Richard Kohn UMD
- Bryan Staley Environmental Research and Education Foundation (EREF)
- Claudia Fabiano EPA OLEM
- Priscilla Halloran EPA OLEM
- Ksenija Janjic EPA OLEM
- Juliana Beecher EPA OLEM

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

Appendix B: Dates of Review

- Energy: October 25, 2022 November 28, 2022
- Industrial Processes and Product Use (IPPU): October 28, 2022 November 30, 2022
- Agriculture: November 15, 2022 December 15, 2022
- Land Use, Land Use Change and Forestry (LULUCF): January 11 February ber 2, 2023
- Waste: October 19, 2022 November 21, 2022

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: 1990-2021* 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.

Chapter 3. Energy

Requests for Expert Feedback for the 1990-2021 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: CO₂ from Fossil Fuel Combustion

- 1. Please provide your overall impressions of the clarity of the discussion of trends in CO₂ 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?
- 4. See attachment 3 for additional questions related to the effort to address an inconsistency in the time series of FHWA's fuel consumption and VMT data.

Fossil Fuel Combustion: CH4 and N2O from Stationary Combustion

 The CH4 and N2O 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 CH4 and N2O 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.

Incorporating CCS Data

1. See attachment 4 for questions and feedback on including Carbon Dioxide Transport, Injection, and Geologic Storage in the Inventory.

Chapter 4. Industrial Processes and Product Use (IPPU)

Requests for Expert Feedback for the 1990-2021 IPPU

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 pg. 6 of attached supporting technical memo on improvements titled "3-Glass_production_improvement_memo_ER."
- Other Process Uses of Carbonates Ceramics Production See pg. 5 of attached supporting technical memo on the proposed methodology titled "4-Ceramics_production_methodology_memo_ER."

Chemicals

- 3. 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 1990-2021.
- 4. 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 for 1990-2021.
- 5. Phosphoric Acid Production Please provide feedback on data sources and assumptions, including:
 - The use of regional production capacity from 2005 to 2016 and from 2017 to 2020 to estimate regional production for those respective years, 2005 to 2016 and from 2017 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 CO₂. 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.
- 6. Ammonia Production See pg. 11 of the attached supporting technical memo on the proposed methodology updates titled "5-Ammonia Improvement Memo" for questions specific to the ammonia production proposed updates.

Metal Production

- 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.
- 8. 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

- 9. 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.
- 10. 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 foreach end use for 1990-2021, nationally and by state.
- 11. Electrical Transmission and Distribution The EPA seeks feedback on the change in methodology for estimating emissions from non-reporting electrical transmission and distribution facilities.
 - We are also seeking feedback on trends in the industry, including whether there were differences in emission rates between (a) utilities that reported to EPA through either the Partnership or the GHGRP and (b) utilities that did not report, both before and after the GHGRP began.
 - In addition, we would appreciate information on the largest sources of SF6 emissions over time, e.g., are the largest source from leaks or from SF6 handling practices. Has this changed over time? How?
 - EPA is also seeking information on whether deliberate overcharging of equipment occurs or has occurred in the past.

Chapter 5. Agriculture

Requests for Expert Feedback for the 1990-2021 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 and 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, Ym, 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 CH₄ emissions from enteric fermentation, and incorporates information on livestock population, feeding practices, and production characteristics.

Chapter 6. Land Use, Land-Use Change, and Forestry (LULUCF)

Requests for Expert Feedback for the 1990-2021 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 Peatlands, are there data sources on the application/consumption of peat by U.S. state that could help refine estimates?

4. For *Flooded Lands Remaining Flooded Lands* and *Lands Converted to Flooded Lands*, the primary data source for flooded land surface area has been updated to the National Wetlands Inventory. A review of the data and methods would be appreciated.

Chapter 7. Waste

Requests for Expert Feedback for the 1990-2021 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 (FNON-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 measurement data on nitrous oxide emissions from industrial wastewater treatment systems,
 - b. Any additional sources of wastewater outflow, BOD generation, N entering treatment, BOD discharged, or N discharged for industries included in the inventory, to capture any changes over the time series,
 - c. National or state level production data for industries included in the inventory,
 - i. In particular, do the data sources for fruits and vegetables processing encompass all U.S. food processing production? Are there data sources other than USDA NASS that would provide a more complete and consistent basis of production over the time series?
 - 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

 EPA has revised the food waste disposal factor used for industrial landfills in the 1990 to 2021 Inventory for select years based on findings of a literature review conducted from 2020 to 2022. A waste disposal factor of 4.86 percent is used for 1990 to 2009 and a revised factor of 6 percent is used for 2010 to the current year. The 6 percent waste disposal factor is derived from recent surveys of the food and beverage industry where approximately 94 percent of food waste generated is repurposed (FWRA 2016). The 4.86% disposal factor is based on available data from a 1993 Report to Congress (EPA 1993). The full memo detailing the findings and calculations for impact on emissions estimates is included as another attachment with this guidance memo (see attachment 3). Please provide any inputs and comments on this change in methodology.

Composting

 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 and/or number of households serviced, and whether the amount of waste composted is consistent from year to year.

Anaerobic Digestion at Biogas Facilities

- 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). 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.

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

- 1) Updates Under Consideration for Ceramics Production GHG Emission Estimates
- 2) Available data on food waste disposed in industrial waste landfills
- 3) Addressing a Time Series Inconsistency in Federal Highway Administration Onroad Activity Data
- 4) Proposed Methodological Refinements for Glass Production
- 5) Updates for Ammonia Production Emissions
- 6) Carbon Dioxide Transport, Injection, and Geologic Storage in the Inventory of U.S. Greenhouse Gas Emissions and Sinks

Updates Under Consideration For Ceramics Production GHG Emission Estimates

Updates Under Consideration for Ceramics Production GHG Emission Estimates

This memorandum discusses updates under consideration for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI) to include process CO₂ emission estimates for ceramics production. The process CO₂ emissions from ceramics production will be reported in Chapter 4 of the GHGI, and full time series data will be reported under Category 2A4a in the Common Report Format (CRF) table reporting.

1 Introduction/Background

Process CO₂ emissions estimates for ceramics production are currently not included in the GHGI. The 2006 IPCC Guidelines identifies four broad source categories to consider for the use of carbonates in the mineral industry: (1) ceramics, (2) other uses of soda ash, (3) non-metallurgical magnesia production, and (4) other uses of carbonates.¹ Currently, the Other Process Uses of Carbonate source category includes process emissions associated with the consumption of soda ash not associated with glass manufacturing and the calcination of limestone and dolomite for flux stone, flue gas desulfurization systems, chemical stone, mine dusting or acid water treatment, and acid neutralization. To improve completeness of the Other Process Uses of Carbonates source category in the GHGI, EPA is outlining methods to include process CO₂ estimates from ceramics production to the GHGI, based on methods recommended in the 2006 IPCC Guidelines. Emissions from fuel used for energy at ceramics facilities are already included in the overall industrial sector energy use (as obtained from the Energy Information Administration (EIA)) and accounted for as part of energy sector emissions in Chapter 3 of the GHGI.

2 Methodology

The ceramic industry comprises a variety of products manufactured from nonmetallic, inorganic materials, many of which are clay-based. The major end use sectors of ceramic products include bricks and roof tiles, wall and floor tiles, table and ornamental ware (household ceramics), sanitary ware, refractory products, vitrified clay pipes, expanded clay products, inorganic bonded abrasives, and technical ceramics (e.g., aerospace, automotive, electronic, or biomedical applications) (EIPPCB 2007).

Most ceramic products are made from one or more different types of clay (e.g., shales, fire clay, and ball clay). The process of manufacturing ceramic products, regardless of the product type or scale, is essentially the same. This process consists of raw material processing (grinding, calcining, and drying), forming (wet or dry process), firing (single or multiple stage firing process), and final processing. Carbon dioxide emissions are produced during the calcination process in the kiln or dryer and from any combustion sources. Process carbon dioxide emissions result from the calcination of carbonates in the raw material (particularly clay, shale, limestone, dolomite, and witherite) and the use of limestone or other additives as a flux (IPCC 2006). In the calcination process, carbonates are heated to high temperatures in a kiln or dryer, producing metal oxides and CO₂. As noted in Section 1 of this memo, emissions from fuel used for energy at ceramics facilities are included in the overall industrial sector energy use and accounted for as part of energy sector emissions in Chapter 3 the GHGI. Emissions from

¹ 2006 IPCC Guidelines, Volume 3 Industrial Processes and Product Use, Chapter 2 Mineral Industry Emissions, Section 2.5 Other Process Uses of Carbonates.

the use of limestone or dolomite as a flux stone are already accounted for in the limestone and dolomite consumption under Other Process Uses of Carbonates (CRF Source Category 2A4), based on activity data obtained from the U.S. Geological Survey (USGS) *Minerals Yearbook: Crushed Stone* (USGS 1995-2020a), and are not considered in these estimates to avoid double counting. Flux stone used during the production of iron and steel was deducted from the Other Process Uses of Carbonates source category estimate and attributed to the Iron and Steel Production source category estimate (CRF Source Category 2C1).

The 2006 IPCC Guidelines include Tier 1, Tier 2, and Tier 3 methodologies for estimating CO₂ emissions from ceramics production. The Tier 1 methodology assumes that limestone and dolomite are the only carbonates contained in the clay use for ceramics production and estimates CO₂ emissions using default limestone and dolomite CO₂ emission factors, a default fraction of limestone versus dolomite consumed, and a default carbonate content for clay if no additional information is available. The Tier 2 method is the same as Tier 1, except it requires national data on the quantity of limestone and dolomite consumed in the clay as opposed to using a default fraction. The Tier 3 method is based on the collection of plant-specific data on the types and quantities of carbonates consumed to produce ceramics, as well as the respective emission factors of the carbonates consumed.

EPA is proposing to use an IPCC Tier 1 method to estimate CO₂ emissions from ceramics production. EPA has not identified the data necessary to implement the Tier 2 or Tier 3 methods. The ceramics production subcategory and the Other Process Uses of Carbonates category are also not a key category in the GHGI.

The IPCC methodology uses the equation 2.14 below to estimate CO_2 emissions from the use of carbonates.

IPCC 2006 Guidelines	Vol 3, Chapter 2	Equation 2.14 (page 2.34)
----------------------	------------------	---------------------------

 $CO_2 = M_c \times (0.85 \, EF_{ls} + 0.15 \, EF_d)$

Where:

 CO_2 = emissions of CO_2 from other process uses of carbonates (metric tons/year) M_c = mass of carbonate consumed (metric tons)

 EF_{ls} or EF_d = emissions factor for limestone or dolomite calcination, metric tons CO_2 /metric ton carbonate

According to the 2006 IPCC Guidelines, the data on carbonates should reflect pure carbonates and not carbonate rock. Consistent with the 2006 IPCC Guidelines, EPA assumes the default carbonate content of clay to be 10%, as no further information is available. The 10% carbonate content is applied to total clay consumed to calculate M_c (mass of carbonate consumed) in the equation above to estimate CO₂ emissions. The 2006 IPCC Guidelines also include the guidance that if national production data for bricks and roof tiles, vitrified clay pipes, and refractory products is used to estimate emissions, then the amount of clay consumed should be calculated by multiplying production with a default loss factor of 1.1. Where consumption data is available and used to estimate emissions, this default loss factor does not need to be applied. This proposed method uses the consumption of clay as activity data, so a loss factor does not apply.

The IPCC default emission factors for limestone and dolomite are presented in Table 1 below, taken from the *2006 IPCC Guidelines* Volume 3, Chapter 2, Table 2.1.

Carbonate	Mineral Name	Emission Factor (metric ton CO ₂ /metric ton carbonate) ^b
CaCO ₃	Calcite ^c or aragonite	0.43971
CaMg(CO ₃) ₂	Dolomite	0.47732

Table 1. CO₂ Emission Factors for Limestone and Dolomite^a

^a Emission factors are based on stoichiometric ratios for carbonate-based minerals.

^b The fraction of emitted CO₂ assuming 100 percent calcination.

^c Calcite is the principal mineral in limestone. Terms like high-magnesium or dolomitic limestones refer to a relatively small substitution of Mg for Ca in the general CaCO₃ formula commonly shown for limestone.

Currently, only national-level activity data on the consumption of clay is available for use in estimating emissions from ceramics production over the 1990 to 2020 time series. The United States Geological Survey (USGS) publishes annual production and consumption information on six types of clay: ball clay, bentonite, common clay, fire clay, fuller's earth, and kaolin. USGS develops domestic production and consumption data based on responses from a voluntary survey of U.S operations. The number of survey respondents and the portion of the industry that the responses represent change annually. In the 2018, USGS reported that 151 of the 224 domestic clay operations responded to the voluntary survey, with those respondents accounting for approximately 64% of the tonnage of total clay and shale sold or used by producers in that year. The survey respondents typically represent between 40 and 70% of the tonnage of total clay sold or used by producers. To address the completeness of the data, USGS estimates production data for nonrespondents based on preliminary survey data, company reports, trade reports, and/or reported prior-year production levels adjusted by industry trends and employment hours (USGS 2022).

To estimate annual process CO₂ emissions, EPA evaluated the end-use for domestic consumption of each type of clay provided by USGS to determine the emissive end-uses that fall into the ceramics production subcategory. Table A-1, included at the end of this memo, provides the list of end-uses for each clay type and indicates which end-uses are emissive. USGS export data is not included for purposes of process CO₂ emissions estimation, as industry reports quantities of exported clay and emissions are associated with the end-use. Limited information is provided on the end-use of imported clay. The amount of total imported clay is between 0.1% and 2.6% of the amount of clay produced across the six types of clays during the 1990 through 2019 time series, as data for 2020 and 2021 were not available at the time of Expert Review. Imported clay data is not accounted for in the preliminary national-level estimates. EPA is assessing how to properly account for the end-uses of imported clay.

3 Preliminary Process CO₂ Emissions Estimates

Using the IPCC Tier 1 calculation methodology and USGS national-level clay production data per clay type for the major emissive end-use sectors of the ceramics production category, EPA used published USGS data (USGS 1994-2020) to develop preliminary process CO₂ emissions for 1990 and 2015 to 2020, shown in Table 2. Data collection efforts for the complete time series are still in process. USGS data for 2021 was not available during Expert Review preparation.

Type of Clay Consumed for Emissive End-Uses for Ceramics Production	1990		2015	2016	2017	2018	2019	2020	
Ball Clay	20.8		41.4	52.3	52.4	44.7	42.9	43.6	
Bentonite	6.2		10.6	1.8	2.5	11.6	11.0	9.2	
Common Clay and Shale	616.0		243.9	301.9	287.9	277.1	263.0	270.7	
Fire Clay	26.0		8.6	16.4	17.6	17.4	18.5	19.5	
Fuller's Earth	1.0		0.0	0.0	0.0	0.0	0.0	0.0	
Kaolin	103.5		69.4	68.9	75.9	65.5	61.9	57.6	
Total 773.5			373.9	441.3	436.3	416.3	397.3	400.6	
^{<i>a</i>} Imported clay data is not accounted for in the preliminary national-level emissions estimates.									

Table 2. Preliminary National Process CO₂ Emissions Estimates from Ceramics Production for 1990 and 2015-2020 (kt CO₂)

4 Uncertainty

The 2006 IPCC Guidelines identify considerations for an uncertainty assessment of process emissions from ceramics production. Uncertainty surround emissions factors are inherently low, as they are based on the stoichiometric ratio of CO₂ released upon calcination. In practice, however, uncertainties arise due to variations in the chemical composition of the carbonate. Uncertainty also arises from activity data. The Guidelines suggest the uncertainty associated with the weighing of carbonates is typically 1-3 percent. The default uncertainty in carbonate content is also indicated as 1-3 percent.

Data on clay consumption are collected by USGS through voluntary national surveys. USGS contacts the owners of U.S. clay operations (i.e., producers of various types of clay) for annual production data. The producers report the annual quantity sold to various end-users and industry types. In 2018, the response rate was approximately 67 percent of operators, representing approximately 64% of the consumption of clay and shale, and the rest is estimated by USGS. Large fluctuations in reported consumption exist, reflecting year-to-year changes in the number of survey responders. The uncertainty resulting from a shifting survey population is exacerbated by the gaps in the time series of reports. The accuracy of distribution by end use is also uncertain because this value is reported by the producer and not the end user. Additionally, there is significant inherent uncertainty associated with estimating withheld data points for specific end uses of clay. Lastly, some of the clay consumed in the United States is reported as "miscellaneous uses;" therefore, it is difficult to accurately allocate this unspecified quantity to the correct end-uses.

According to the USGS, uncertainty in the activity data is also a result of how U.S. clay producers classify the clay produced (USGS 2022), but this variability in terminology, however, does not affect emission estimates which are based on total amounts of clay used for emissive end-uses:

"Clay-mineral terminology often is used inconsistently and can vary depending on geologic origin, mineralogy, and commercial application. For example, bentonite was originally defined as a clay produced by chemical alteration of igneous rock (usually tuff or volcanic ash), yet clay from many deposits of nonvolcanic origin is sold as bentonite. The terms ball clay, fire clay, and kaolin are sometimes used interchangeably because the kaolinite minerals in each can be distinguished based only on particle size and degree of ordering within the atomic structure. The term fuller's earth has no mineralogical meaning and often is applied to any clay with absorptive qualities (Eisenhour and Reisch, 2006; McCuistion and Wilson, 2006; Pickering and Heivilin, 2006). Consequently, data presented for one specific clay type may include one or more other varieties. The USGS does not attempt to precisely identify clay types, but rather uses the terminology as reported."

Uncertainty in the estimates also arises in part due to the variations in the carbonate content of the various clays. As discussed above, as no information is available on the carbonate content for each clay, default fractions of limestone and dolomite consumed and a default carbonate content for clay are used.

5 Request 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 IPCC assumption of 10% carbonate content value applied to total clay consumed for use of estimating clay carbonate content on a national level. EPA seeks feedback on additional sources of carbonate content per type of clay.
- 2. EPA is considering applying the IPCC Tier 1 carbonate values of 85% limestone and 15% dolomite to the emissions calculation for clay usage. EPA seeks feedback on other representations for the national level.
- 3. EPA intends to use the USGS production values, defined as clay sold or used by producers, to estimate process CO₂ emissions for each of the six types of clays. To properly account for imported clay consumption, unless additional information is available, EPA will assume that the imported clay is consumed for ceramic production at the same proportions as domestically produced clay. EPA seeks feedback if additional information is available on the end-use of imported clays.
- 4. EPA is assessing the completeness of the USGS dataset and survey responses over the time series beginning with 1990, in both number of operations and the tonnage of clay and shale used or sold. EPA seeks additional data on the response rate over the time series.
- 5. EPA is proposing an emissions estimation methodology that does not currently account for differences in carbonate content among the various clays consumed to produce ceramics. Given this methodology, EPA seeks data on the total amount of clay, summed across all clay types, sold or used by end-use.

6 References

IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change. Volume 3, Industrial Processes and Product Use, Chapter 2, Mineral Industry Emissions. [H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.)]. Hayama, Kanagawa, Japan. 2006.

Eisenhour, Don, and Reisch, Franz, 2006, Bentonite, in Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, S.T., eds., Industrial minerals and rocks (7th ed.): Littleton, CO, Society for Mining, Metallurgy, and Exploration Inc., p. 357–368.

European Integrated Pollution Prevention and Control Bureau (EIPPCB) 2007. *Reference Document on Best Available Techniques in the Ceramic Manufacturing Industry*, European Commission. August 2007.

McCuistion, Jason, and Wilson, Ian, 2006, Ball clays, in Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, S.T., eds., Industrial minerals and rocks (7th ed.): Littleton, CO, Society for Mining, Metallurgy, and Exploration Inc., p. 343–356.

Pickering, S.M., Jr., and Heivilin, F.G., 2006, Fuller's earth, in Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, S.T., eds., Industrial minerals and rocks (7th ed.): Littleton, CO, Society for Mining, Metallurgy, and Exploration Inc., p. 373–381.

United States Geological Survey (USGS) (1994-2020). *1994-2020 Minerals Yearbooks, Clay and Shale, Advance Release*. U.S. Geological Survey, Reston, VA.

USGS (2022). 2018 Minerals Yearbook, Clay and Shale [Advanced Release]. U.S. Geological Survey, Reston, VA. March 2022.

USGS (1995 through 2020a) *Minerals Yearbook: Crushed Stone*. U.S. Geological Survey, Reston, VA.

Ball Clay	Emissive?	Bentonite	Emissive?
Fillers, extenders, and binders	N	Pet waste absorbents	N
Floor and wall tile	Y	Other absorbents	N
Dinnerware	Y	Adhesives	N
Miscellaneous ceramics	Y	Animal feed	N
Pottery	Y	Drilling mud	N
Refractories	Y	Filler and extender applications	N
Sanitaryware	Y	Filtering, clarifying, decolorizing,	N
		mineral oils and greases,	
		vegetable oils, desiccants	
Miscellaneous:		Foundry sand	N
Chemical manufacturing	N	Pelletizing (iron ore)	N
Heavy-clay products	Y	Waterproofing and sealing	N
Waterproofing seals	N	Miscellaneous civil engineering	N
Refractories	Y	Miscellaneous refractories and	Y
		kiln furniture	
Paint	N	Miscellaneous:	
Absorbents	N	Ceramics	Y
Brick (common)	Y	Chemical manufacturing	N
Flue lining	N	Clarifying and decolorizing	N
Glazes	N	Heavy-clay products	Y
Drilling mud	N	Oil and grease absorbents	N
Unknown Uses	N	Refractories	Y
		Asphalt emulsions	N
		Asphalt tile	N
		Portland cement	N
		Ceramic floor and wall tile	Y
		Face brick	Y
		Fertilizers	N
		Firebrick, blocks and shapes	Y
		Gypsum products	N
		Ink	N
		Kiln furniture	Y
		Mineral wool and insulation	N
		Oil well sealing	N
		Paper coating and filling	N
		Plastics	Ν
		Pottery	Y
		Roofing tile	Y
		Catalysts (oil-refining)	Y
		Rubber	N
		Unknown uses	N

Table A-1. End Uses of Ball Clay, Bentonite, Common Clay, Fire Clay, Fuller's Earth, and Kaolin

Common Clay	Emissive?	Fire Clay	Emissive?
Floor and wall tile:	Y	Ceramics and glass	Y
Ceramic	Y	Heavy-clay products and	
		lightweight aggregates:	
Other	Y	Common brick	Y
Heavy-clay products:		Concrete block	N
Brick, extruded	Y	Portland cement	N
Brick, other	Y	Structural concrete	N
Drain tile and sewer pipe	Y	Terra cotta	Y
Flowerpots	Y	Unknown uses	N
Flue linings	Y	Refractories:	
Structural tile	Y	Firebrick, block, and shapes	Y
Other	Y	Grogs and calcines	Y
Lightweight aggregate:		Other refractories:	Y
Concrete block	N	Foundry sand	N
Highway surfacing	N	Grogs and calcines	Y
Structural concrete	N	Mortar and cement	N
Miscellaneous	N	Common brick	N
Portland and other cements	N	Flue linings	N
Refractories:		Plug, tap and wad	N
Block and shapes	Y	Misc. refractories	Y
Firebrick	Y	Miscellaneous:	
Grogs and calcines	Y	Animal feed	N
Mortar and cement	N	Floor tile	Y
Misc. refractories	Y	Pottery	Y
Miscellaneous:		Wall tile	Y
Exports reported by producers	N	Quarry tile	Y
Misc. civil engineering and sealings	N	Misc. ceramics	Y
Misc. fillers, extenders, and	N	Unknown uses	N
binders			
Pottery	Y		
Roofing granules	Y		
Misc. ceramics	Y		
Asphalt emulsion	N		
Asphalt tile	N		
Wall board	N		
Pelletizing (iron ore)	N		
Unknown uses	N		

Table A-1. End Uses of Ball Clay, Bentonite, Common Clay, Fire Clay, Fuller's Earth, and Kaolin (continued)

Fuller's Earth	Emissive?	Kaolin	Emissive?	
Miscellaneous:		Ceramics:		
Catalysts (oil-refining)	N	Catalyst (oil and gas refining)	Y	
Animal feed	N	Electrical porcelain	Y	
Animal oils	N	Fiberglass, mineral wool	Y	
Gypsum products	N	Fine china and dinnerware	Y	
Miscellaneous fillers, extenders, and binders	N	Floor and wall tile	Y	
Miscellaneous filtering, clarifying	N	Pottery	Y	
Plastics	N	Roofing granules	Y	
Wallboard	N	Sanitaryware	Y	
Water treatment and filtering	N	Miscellaneous	Y	
Waterproofing and sealing	N	Chemical manufacture	N	
Electrical porcelain	Y	Fillers, extenders, binders:		
Chemical manufacturing	N	Adhesives	Ν	
Drilling mud	N	Fertilizer	N	
Fertilizers	N	Paint	N	
Miscellaneous absorbents	N	Medical, pharmaceutical, cosmetic	N	
Pesticides	N	Paper coating	Ν	
Portland cement	N	Paper filling	Ν	
Roofing granules	Y	Pesticide	N	
Refractories	Y	Plastics	N	
Unknown uses	N	Rubber	N	
		Miscellaneous	N	
		Heavy-clay products:		
		Brick (common)	Y	
		Portland and other cements	N	
		Refractories:		
		Firebrick, blocks and shapes	Y	
		Grogs and calcines	Y	
		High-alumna brick, specialties, kiln furniture	Y	
		Other		
		Foundry sand	N	
		Mortar	N	
		Cement	N	
		Misc. refractories	Ŷ	
		Miscellaneous applications:		
		Linoleum and asphalt tile	N	

Table A-1. End Uses of Ball Clay, Bentonite, Common Clay, Fire Clay, Fuller's Earth, and Kaolin (continued)

Available Data on Food Waste Disposed In Industrial Waste Landfills



Memorandum

То:	Lauren Aepli, U.S. EPA
From:	Kate Bronstein, Emily Thompson, RTI
Date:	August 18, 2022
Subject:	Available data on food waste disposed in industrial waste landfills

Background

Emissions from industrial waste landfills are modeled using secondary data and default emission factors for two industrial sectors – pulp and paper manufacturing, and food and beverage processing. This memorandum focuses on the food and beverage processing sector for which there has historically been limited publicly available information on the quantity of solid waste generated that is disposed in industrial waste landfills.

Data reported to the EPA's Greenhouse Gas Reporting Program (GHGRP) provides some insight into disposal quantities, but this dataset is limited to facilities meeting the threshold reporting requirements (i.e., it is not a comprehensive data source). Previous analyses of the GHGRP Subpart TT data were completed by RTI for the 2012 and 2016 reporting years (RTI, 2018¹). The major findings were that very few facilities from the food and beverage processing sector report under Subpart TT and the data are inconsistent with scope of Inventory for this sector.

Because of the lack of transparency and large difference in waste disposal data for the food and beverage sector, we continue to use a Tier 1 approach to estimating emissions for the Inventory: food waste landfilled for each year from 1940 to the current Inventory year equals the ratio of food produced to food disposed in 1985 (4.86%) multiplied by the food produced (collected from the U.S. Department of Agriculture Quick Stats) in the year in question. The quantity of produced to landfilled in 1985 was 71.125 million metric tons (MMT) to 3.26 MMT. This static food disposal factor (4.86%) is applied to the total weight of food produced each year of the Inventory. Food waste landfilled in 1985 is sourced from EPA (1993)² and has been the most comprehensive source of information on food waste landfilled to date.

To investigate a potential improvement to the Inventory and in response to comments received during a previous expert review, we completed a literature scan to identify data sources with estimates of food waste being disposed in industrial waste landfills with a goal of updating the current food waste disposal factor and gaining new insights into disposal practices for this sector.

Key Points from the 2012 Memo Prepared for EPA ORCR

The EPA received 1990-2018 expert review comments from the waste management industry, including the National Waste and Recycling Association, citing a December 2012 memo prepared for EPA's Office of Resource Conservation and Recovery (ORCR) which concluded that solid waste from the food processing sector is primarily managed by utilization which suggests that very little waste from that sector is landfilled. The memo summarized available data

¹ RTI (2018) Comparison of industrial waste data reported under Subpart TT and the Solid Waste Chapter of the GHG Inventory. Memorandum to Rachel Schmeltz, U.S. EPA/CCD on October 12, 2018.

² EPA (1993) Anthropogenic Methane Emissions in the United States, Estimates for 1990: Report to Congress, U.S. Environmental Protection Agency, Office of Air and Radiation, Washington, DC. EPA/430-R-93-003. April.

sources on food waste generation and management of industrial food waste and specifically looked at fruits, vegetable, meat, and brewery wastes. The main data source was the U.S. Department of Agriculture (USDA) Economic Research Service (ERS) 2011 report, Consumer-Level Food Loss Estimates and Their Use in the ERS Loss-Adjusted Food Availability Data.

The data presented in the memo are significantly different from that used by the Inventory (see **Table 1**). The memo to ORCR does imply all food waste is landfilled; several anecdotal points of evidence regarding the high usage of the excess food are noted. For the purposes of the Inventory, a waste disposal factor or actual quantities of annual disposed waste are needed. No sources reviewed by the contractor appear to have identified a waste disposal factor for the main categories of food waste – fruits, vegetables, and meats. Waste landfilled estimates are provided for brewer's yeast and are approximately 12,000 tons per year between 2000 to 2010 (not presented in Table 1). The amount of malt beverage production (barrels per year) is multiplied by a factor of 0.12 pounds of waste per barrel; the factor is the percentage one brewing company landfilled in 2011. Brewer's yeast is not included in the Inventory for industrial waste landfills primarily because it is not a major waste stream compared to fruits and vegetables.

Table 1. Percentage differences between the Inventory estimated amounts of food processing waste landfilled (Inventory) and the December 2012 memo estimates of food loss using the USDA ERS data (Memo to ORCR), units = 1000 tons

	Inver	ntory	Memo to ORCR		Inventory		Memo to ORCR		Inventory		Memo to ORCR	
Year	Meat Production	Meat Landfilled	Meat Waste	% Diff Meat	Veg Production	Veg Landfilled	Veg waste	% Diff Veg	Fruit Production	Fruit Landfilled	Fruits waste	% Diff Fruit
<u>'00</u>	37,365	1,815	12,747	-602%	28,586	1,389	18,778	-1252%	22,309	1,084	9,184	-747%
'01	37,534	1,824	12,715	-597%	25,064	1,218	18,450	-1415%	19,911	967	9,045	-835%
'02	38,731	1,882	13,275	-605%	27,480	1,335	18,740	-1304%	20,206	982	8,668	-783%
'03	38,642	1,877	13,281	-607%	25,889	1,258	19,318	-1436%	18,856	916	8,918	-873%
'04	38,620	1,876	13,608	-625%	27,858	1,353	19,347	-1329%	19,900	967	9,066	-838%
'05	39,192	1,904	13,721	-621%	25,694	1,248	19,277	-1444%	17,239	838	8,590	-926%
ʻ06	40,341	1,960	13,880	-608%	26,620	1,293	18,780	-1352%	16,306	792	8,296	-947%
'07	41,226	2,003	13,956	-597%	28,761	1,397	19,286	-1280%	15,960	775	7,927	-922%
'08	42,301	2,055	13,702	-567%	27,390	1,331	18,571	-1296%	17,721	861	7,643	-788%
ʻ09	40,858	1,985	13,440	-577%	29,344	1,426	18,866	-1223%	17,158	834	7,825	-839%

Summary of Available Literature

An internet search was conducted to find quantitative data on the following:

- The type and quantity of waste generated at food processing facilities; and,
- The amount of food waste disposed in industrial waste landfills.

Literature was gathered (**Appendix A**) using key search terms as referenced in **Appendix B**. Most of the literature qualitatively discusses the types of waste generated, utilization of by-products and solid residuals, waste management practices, and treatment and disposal methods in the food processing industries. Qualitative data collected from literature shows the types of waste generated from food processing industries that can potentially be disposed of in an industrial

waste landfill. The types of food waste include by-products from fruit and vegetable processing industries (including grape pomace, apple pomace, stems, leaves, skins, and seeds); primary treatment system products in meat and poultry processing industries (including sludge and skimming); eggshells from egg processing industries; and, solid waste generated from seafood processing industries. Various other waste management and disposal methods are discussed throughout the literature for solid food waste residuals from food processing facilities, including by-product utilization as animal feed or fertilizer, land application, composting, biological treatment, and thermal treatment.

There is limited quantitative data on food waste from food manufacturing facilities that is disposed in industrial waste landfills. The most useful resources include Dou et al. (2016) who cross-referenced data collected by Business for Social Responsibility (BSR), the Food Waste Alliance, and EREF. The Food Waste Alliance has contracted out their 'Analysis of U.S. Food Waste Among Food Manufacturers, Retailers, and Wholesalers' survey to BSR since 2012. To date, results from 4 surveys have been published – 2012, 2013, 2014 and 2016, but only the BSR (2013)³ report extrapolates survey data to the entire U.S. market.

Dou et al. (2016) note that "there are roughly 27,400 locations for the food processing/manufacturing sector in the U.S. (U.S. Census Bureau, 2015) generating about 80 MMT of food waste annually." The authors cross-reference survey data from Food Waste Alliance/BSR (2013) which represented 17 percent (13 respondents) of the food manufacturing sector. Food Waste Alliance/BSR (2013) extrapolated the survey results and estimated approximately 1.1 MMT (5.4%) of food waste from food manufacturers was disposed of in landfills or by incineration in 2011; in other words, 94.6 percent of waste volumes from the food manufacturing industry was diverted to other uses. The most recent Food Waste Alliance/BSR survey (FWRA, 2016) also states that 94% of food waste from the food manufacturing sector was repurposed as animal feed or for land application (survey data based on 9 respondents; was not extrapolated to the entire U.S. market). Estimated amounts going to landfills versus amounts being incinerated were not estimated by the Food Waste Alliance, BSR, or Dou et al. (2016). Knowing that food waste is typically very wet with a low calorific value, we expect most of what is not beneficially reused (e.g., donated, used for animal feed, digested, land applied) is likely landfilled versus incinerated.

Krones, Chertow, and Li (2020) authored the report, *Making up for Lost Time (and Space): Quantifying Non-hazardous Industrial Waste Generation in the U.S.*⁴, a comprehensive account of U.S. non-hazardous industrial waste tonnages and compositions over three decades for the Environmental Education and Research Foundation (EREF). According to Table ES-1 from Krones et al. (2020), the food waste sector accounts for 18% of the non-hazardous industrial waste tonnage. This amount was determined by combining the following four independent methods to obtain waste tonnages for all waste sectors: (1) historical forecasting using empirical results from past studies; (2) spatial up-scaling using data from the Pennsylvania Residual Waste program; (3) material balance using publicly available data on industry inputs and outputs; and (4) comparison with European waste accounts. The sectors accounted for include textile, apparel, and leather manufacturing and products sectors; wood products sectors; paper and printing sectors; petroleum and coal products

³ Business for Social Responsibility (BSR), 2013. Analysis of U.S. Food Waste Among Food Manufacturers, Retailers, and Restaurants. (Available at: <u>http://www.foodwastealliance.org/wp-content/uploads/2013/06/FWRA_BSR_Tier2_FINAL.pdf</u>) The key findings on food manufacturing from the BSR (2013) survey data, when extrapolated to the entire U.S. for 2011, estimates that the manufacturing sector generated approximately 20 MMT (44.3 billion pounds) of food waste, but 94.6 percent was diverted from landfills to higher uses, such as donation and recycling. This equates to 1.1 MMT (2.4 billion pounds) of food waste from the manufacturing sector being disposed (landfill or incineration) in 2011. BSR was not able to separately estimate quantities disposed in a landfill versus the amount incinerated. The survey respondents represented 17 percent of the U.S. manufacturing sector and 30 percent of the retail and wholesale sectors.

⁴ Krones, Chertow, and Li, 2020. Making up for Lost Time (and Space): Quantifying Non-hazardous Industrial Waste Output and Beneficial Use Opportunities in the US. (Available at: <u>https://erefdn.org/wp-content/uploads/2021/01/EREF_Final-Report_NHIW_1216.pdf</u>)

sectors; chemicals, plastics, and rubber sectors; nonmetallic minerals sectors; and primary metal, foundries, and fabricated metal sectors. The industry sectors within the study were determined by their NAICS codes (e.g., 311 for food manufacturing; 312 for beverage and tobacco manufacturing). The food, beverage, and tobacco manufacturing and production sectors contributed approximately 43.78 to 45.83 MMT of non-hazardous industrial waste in 2015, with the fruit and vegetable processing wastes and meat processing wastes being the largest contributors with waste amounts of 23.67 MMT and 12.85 to 12.89 MMT, respectively. These estimates are food waste generated, not disposed. The authors noted three main complications when accounting for food, beverage, and tobacco sector solid waste estimations: (1) many food processing residuals are managed as wastewaters, so generated food waste solids are sometimes only recovered in wastewater treatment plant sludge; (2) agriculture and food processing facilities are often co-located and closely linked, so allocating food wastes can be difficult; and (3) traditionally, food processing residuals are beneficially used as animal feed, fertilizer, etc., so solid food wastes may be underreported if they are not managed as waste at their facility.

In addition to the above literature, we also investigated data from EPA's Excess Food Opportunities Map⁵. This map includes a variety of potential excess food generators, including 59,914 food manufacturing and processing facilities (in Version 2.1). In addition to the facility name and location, the primary NAICS code and a low and high estimate of the potential food waste is included. A large portion of the facilities appear to be retail based on the NAICS code description (17,223 are retail bakeries) and may not be relevant to industrial waste landfills. The amount of excess food generated from all facilities, excluding retail bakeries, ranges from 2.5 to 8.1 MMT. Facility food waste averages range from 69 to 220 MMT. We assume the majority of this food waste is going to an MSW landfill versus an industrial waste landfill. Disposition of the excess food is not covered in the Excess Food Opportunities Map.

EPA's *Wasted Food Measurement Methodology Scoping Memo⁶* estimates that 37.8 MMT of excess food and food waste is generated by the industrial sector (food and beverage manufacturers) in 2016. According to the "Manufacturing and Processing Sector Excess Food and Food Waste Management Profile" (Figure 7 within the scoping memo), approximately 49% (18.5 MMT) of excess food and food waste was managed by reuse as animal feed, 22% (8.3 MMT) was reclaimed as land application (e.g., fertilizer), 14% (5.3 MMT) was anaerobically digested, 9% (3.3 MMT) was managed as food donations, 4% (1.5 MMT) was MSW landfilled, 2% (0.6 MMT) was composted, 1% (0.2 MMT) was biochemically processed, and 0.3% (0.1 MMT) was combusted. The scoping memo also noted that industrial sector estimates would not be included within EPA's 2018 *Advancing Sustainable Materials Management: Facts and Figures* ("Facts and Figures") report because industrial food manufacturing and processing sources are out of EPA's annual "Facts and Figures" report scope. EPA's *Advancing Sustainable Materials Management: 2018 Fact Sheet* ⁷ and *Advancing Sustainable Materials Management: 2018 Tables and Figures*⁸ were reviewed, and the reports do not include industrial food process waste estimates.

EPA's 2018 Wasted Food Report⁹, which are the detailed estimates using the EPA's Scoping Memo methodology, estimates 3.3% (1.3 million tons landfilled to 39.8 million tons generated) of food waste from the industrial sector (food and beverage manufacturers) is landfilled; however, we believe this excess food is assumed to go to MSW versus industrial waste landfills.

⁵ <u>https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map</u>

⁶ EPA, 2020, <u>https://www.epa.gov/sites/default/files/2020-06/documents/food_measurement_methodology_scoping_memo-6-18-20.pdf</u>.

⁷ EPA, 2020, https://www.epa.gov/sites/default/files/2021-01/documents/2018_ff_fact_sheet_dec_2020_fnl_508.pdf.

⁸ EPA, 2020, https://www.epa.gov/sites/default/files/2021-01/documents/2018_tables_and_figures_dec_2020_fnl_508.pdf.

⁹ EPA, 2020, <u>https://www.epa.gov/sites/default/files/2020-11/documents/2018_wasted_food_report.pdf</u>.

Conclusions and Recommendations

The current Inventory method estimates approximately 4.2 MMT to 4.4 MMT as being disposed annually from 2007 to 2019, which is approximately 74 percent greater than the 1.1 MMT Food Waste Alliance estimate from 2011 (BSR, 2013; [44.3 billion pounds generated – (44.3 billion x 94.6% diverted) = 2.4 billion pounds, converted to metric tons = 1.1 MMT]. However, if we assume 6% of industrial waste generated is disposed (using the Food Waste Alliance estimate that 94% is repurposed), the annual Inventory food waste disposal estimates would be approximately 1 MMT higher, ranging from 5.2 MMT to 5.5 MMT annually from 2007 to 2019, but still aligned with the current Inventory estimates. The impact to net methane emissions is an approximately 0.1 MMT increase as shown in **Figure 1**, or approximately 11% higher (from 0.67 to 0.74 MMT for industrial waste landfills in 2019) when the 6% factor is applied. While the impact to the net industrial waste emissions is insignificant, the impact to total net emission from both MSW and industrial waste landfills is approximately 0.65% (not shown; difference between 4.58 MMT to 4.61 MMT in 2019).

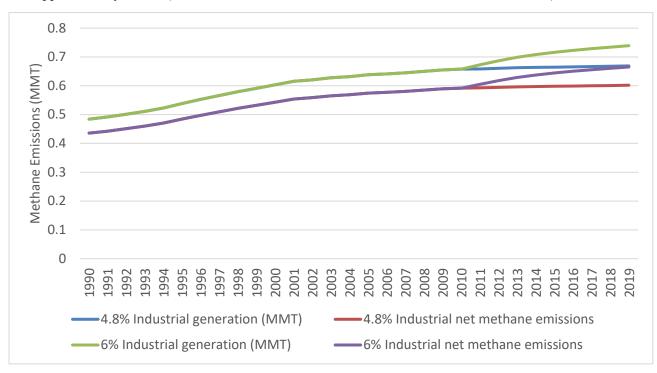


Figure 1. Impact from increasing the food waste disposal factor to 6% between 2010 to 2019 on total net emissions from industrial waste landfills

The large difference between the mass of food waste disposed may be because the Food Waste Alliance/BSR extrapolated survey data to the entire U.S. based on sector revenue data versus production data, which is what the Inventory uses. Production data is a better estimate when quantifying waste streams because revenue fluctuates with the markets (domestic and international) and may not accurately capture local reuse markets, while production is more closely tied to individual plant capacity, process operations, and local markets for reuse opportunities. On the other hand, the Inventory estimates are relatively close to the lower end of EPA's Excess Food Opportunities Map data (2.5 MMT to 8.1 MMT) with the understanding that not all of this food waste is landfilled; we believe the higher end estimate likely consists of excess goods being disposed in MSW landfills versus industrial waste landfills.

Through this effort, we have confirmed that there is limited quantitative data to support annual estimates of the amount of food waste being disposed in industrial waste landfills from food processing facility data. We also know that the GHGRP Subpart TT data does not cover the scope of the Inventory. There remains a data gap for regularly updated disposal estimates for the food and beverage processing sector.

The current Inventory method relies on regularly published food production data, but still has uncertainty because dated activity data are used to estimate food waste disposed. Uncertainties in the current Inventory method arise because (1) it relies on production data and a disposal factor (4.86%) based on 1985 survey data and (2) there has been increased attention through corporate social responsibility, composting networks, zero waste goals, etc. in the past two decades to decrease the amount of waste disposed. For example, many major food manufacturing companies (e.g., Nestle, Unilever) have adopted zero waste goals and efforts to increase the reduction, reuse, and recycling to prevent food waste from entering landfills, but data confirming these goals are being met were not available in the literature scan. The EPA's Excess Food Opportunities data is reassuring in that the Inventory is not significantly over- or under-estimating the amount of waste landfilled; however, this is not a regularly updated data source.

Based on these findings, we recommend using the current method where a food disposal factor is applied to food production data and applying the existing 4.86% disposal factor between 1990 to 2009 and switching to a 6% disposal factor in 2010 and applying the 6% factor for all later years (i.e., the FWRA, 2016 estimate that 94% of food waste generated is repurposed). We recommend applying the same uncertainty factor (50% for industrial landfill activity data) applied to the 4.86% disposal factor and the 6% disposal factor because the survey data was not comprehensive.

ID	Resource Title, Author, Year Published	Type and Qua Generated	antity of Solid Waste	Disposal Methods	Page Numbers	URL
A	A Guide for Waste Management in the Food Processing Industry Katsuyama, 1979	Type Quantity	Fruit and Vegetable; Seafoods; Shellfish 	Reports on utilization and disposal of solid residuals from fruit/vegetable and seafood processing.	Utilization of Solid Residuals (pp. 209- 220); Disposal Methods (pp. 221- 236); Landfills (pp. 226-229)	https://p2infohouse.o rg/ref/31/30495.pdf
В	Food Waste Disposal and Handling - Practices to Consider Kennedy, 2013	Type Quantity		Overview of composting and anaerobic digestion. Not specific.		https://www.wasteca re.com/Articles/Food -Waste-Disposal- and-Handling.htm
С	Fruit and Vegetable Processing World Bank, 1998	Type Quantity	Fruit and Vegetable Reported in Table 2			https://www.ifc.org/w ps/wcm/connect/142 cdda6-8f23-4a21- 974a- 43eb000948d3/fruita ndvg_PPAH.pdf?MO D=AJPERES&CVID =jqeDiAw
D	Solid Waste Management in the Food Processing Industry National Canners Association, 1973	Type Quantity	Canned and cured seafood; Canned specialties; Canned fruits and vegetables; Dehydrated food products; Pickles; Frozen packaged fish; Frozen fruits and vegetables Reported in Table 2	Dry and wet disposal methods vary. Each section has a "Residual Handling and Disposal"	pp. 173-200	https://nepis.epa.gov /Exe/ZyPDF.cgi/910 0XH2G.PDF?Docke y=9100XH2G.PDF
E	Food processing waste: Problems, current management, and prospects for utilisation of	Туре	Fruit and Vegetable		p. 522	https://reader.elsevie r.com/reader/sd/pii/S 1364032113003936 ?token=351FAF2B5

Appendix A. Literature Gathered from Internet Search

ID	Resource Title, Author, Year Published	Type and Quantity of Solid Waste Generated		Disposal Methods	Page Numbers	URL
	the lignocellulose component through enzymesynergistic degradation Dyk et al., 2013	Quantity	Reported in Table 1 (too detailed for the inventory)			9DB5FE7AA577186 9BA7ADE834415F4 A26D3DE919B1F18 9F1ECBEF2AE5B5F DAADD44FA3FE89 762E89D57146E
F	Waste Management and Utilization in Food Production and Processing CAST, 1995	Type Quantity	Grain Processing for Oils; Fruit and Vegetable; Dairy; Meat and Poultry; Seafood Quantities reported in corresponding sections	Disposal methods vary among food processing industry types. Landfilling for meat and poultry waste referenced on p. 93.	Processing Wastes (pp. 67-97)	https://www.cast- science.org/wp- content/uploads/199 5/10/CAST_R124_W aste-Management- and-Untilization.pdf
G	Assessing U.S. food wastage and opportunities for reduction Dou et al., 2016	Type Quantity	Food production of Vegetables; Fruit; Meat/Poultry/ Fish 1.1 MMT Estimated food wastage recorded in Table 1 for the U.S.; text and Figure 3 for waste disposed by food waste manufacturers	Landfill/incineration estimates for the entire food manufacturing sector	Section 3 (pulls from Food Waste Alliance survey data)	https://reader.elsevie r.com/reader/sd/pii/S 2211912415300195 ?token=7563C87F6 B539610CF4D7239 C824D0D3668AE3C B5A304002D939904 993AF39A545B1634 A2DC5BF9FF795F5 2A0900354D
H	Food Waste Treatment Methodologies Arvanitoyannis, 2018	Type Quantity		Describes composting, anaerobic/aerobic digestion, thermophilic anaerobic digestion, sequencing batch reactor, electrodialysis, wet oxidation, pyrolysis, incineration, and solid fermentation and ozonation.	pp. 359-399	https://www.science direct.com/book/978 0123736543/waste- management-for- the-food- industries?via=ihub=
Ι	Wine Waste Management: Treatment Methods and	Туре	Grapes	SBR (Sequencing Batch Reactor),	pp. 418-427	https://www.science direct.com/book/978

ID	Resource Title, Author, Year Published	Type and Qua Generated	ntity of Solid Waste	Disposal Methods	Page Numbers	URL
	Potential Uses of Treated Waste Arvanitoyannis, 2018	Quantity		Anaerobic/Thermophilic Anaerobic digestion, Incineration, Pyrolysis, Ozonation, Wet Oxidation		0123736543/waste- management-for- the-food- industries?via=ihub=
J	Olive Oil Waste Management: Treatment Methods and Potential Uses of Treated Waste Arvanitoyannis, 2018	Type Quantity	Olives	Bioremediation, composting, incineration, pyrolysis, gasification, evaporation, membrane processes, electrolysis, ozonation, digestion, coagulation/flocculation/pr ecipitation, distillation	pp. 456-489	https://www.science direct.com/book/978 0123736543/waste- management-for- the-food- industries?via=ihub=
К	Fruit/Fruit Juice Waste Management: Treatment Methods and Potential Uses of Treated Waste Arvanitoyannis, 2018	Type Quantity	Fruit Amounts discussed in pp. 587-590	Thermal processes, evaporation, membrane processes, anaerobic digestion, anaerobic co- digestion, biodiesel production, combustion, supercritical and subcritical fluid extraction, coagulation composting	Treatment Methods (pp. 570-575)	https://www.science direct.com/book/978 0123736543/waste- management-for- the-food- industries?via=ihub=
L	Cereal Waste Management: Treatment Methods and Potential Uses of Treated Waste Arvanitoyannis, 2018	Type Quantity	Wheat; rice; maize; barley; oats; rye; sorghum 	Pyrolysis, gasification, composting, combustion, biogas	pp. 659-681	https://www.science direct.com/book/978 0123736543/waste- management-for- the-food- industries?via=ihub=
М	Vegetable Waste Management: Treatment Methods and Potential Uses of Treated Waste Arvanitoyannis, 2018	Type Quantity	Vegetables	Thermal processes, evaporation, membrane processes, anaerobic digestion, anaerobic co-digestion, biodiesel spraying, combustion, transesterification, coagulation, composting	pp. 704-715	https://www.science direct.com/book/978 0123736543/waste- management-for- the-food- industries?via=ihub=

ID	Resource Title, Author, Year Published	Type and Qu Generated	antity of Solid Waste	Disposal Methods	Page Numbers	URL
N	Meat Waste Management: Treatment Methods and Potential Uses of Treated Waste Arvanitoyannis, 2018	Type Quantity	Meat Amounts discussed in pp. 766-768	Primary and Secondary Treatment (Anaerobic/aerobic digestion, thermal treatments, composting)	pp. 768-782	https://www.science direct.com/book/978 0123736543/waste- management-for- the-food- industries?via=ihub=
0	Dairy Waste Management:Treatment Methods andPotential Uses of TreatedWasteArvanitoyannis, 2018	Type Quantity	Amounts discussed on p. 801-802	Aerobic/anaerobic treatment, membrane treatment, constructed wetlands, coagulation/electrocoagul ation/flocculation/precipita tion, bioremediation	pp. 804-819	https://www.science direct.com/book/978 0123736543/waste- management-for- the-food- industries?via=ihub=
Ρ	Fish Waste Management: Treatment Methods and Potential Uses of Treated Waste Arvanitoyannis, 2018	Type Quantity	Amounts discussed on p. 861	Hydrolysis, bioremediation, anaerobic treatment, filtration/screening, misc/multifunctional methods	pp. 864-882	https://www.science direct.com/book/978 0123736543/waste- management-for- the-food- industries?via=ihub=
Q	Underutilized Resources as Animal Feedstuffs ANRC, 1983	Type Quantity	Fruit; Vegetable; Dairy; Seafood; Poultry; Red Meat Amounts discussed on pp. 5-6	Landfills, field spreading, activated sludge, use of residuals for by-products	pp. 5-41	https://www.nap.edu/ read/41/chapter/3#8
R	Industrial Waste Treatment Handbook, Chapter 10- Waste from Industries (Case Studies) Woodard and Curran Inc., 2006	Type Quantity	Frozen Foods; Wine; Bottled Soft Drinks; Beef/Pork/ Red Meat Production; Rendering of by- products 	Composting, land disposal, anaerobic treatments, fertilizer (discusses the processes; does not quantify)	Prepared Frozen Foods (pp. 426-434); Wine Making Industry (pp. 455-459); Production of Bottled Soft Drinks (pp. 468- 472); Production and Processing of Red Meat (pp. 472-479); Rendering (pp. 479- 486)	https://www.science direct.com/science/a rticle/pii/B978075067 9633500126

ID	Resource Title, Author, Year Published	Type and Quantity of Solid Waste Generated	Disposal Methods	Page Numbers	URL
S	Global Food Losses and Food Waste	Extent, causes, and prevention of Food Waste. Relevant terminology and global statistics.			http://www.fao.org/3/ a-i2697e.pdf
	FAO, 2011				
Т	A Framework for Assessing the Effects of the Food System	Food chain supply system overview that highlights the food processing and manufacturing industry in the U.S.			https://www.ncbi.nlm .nih.gov/books/NBK3 05181/
	NRC, 2015				
U	Going Beyond Zero Waste to Landfill Unilever, 2019	Zero waste goals and how they are maintained as described by Unilever.			https://www.unilever. com/sustainable- living/reducing- environmental- impact/waste-and- packaging/going- beyond-zero-waste- to-landfill/
V	Reducing Food Loss and Waste Nestle, 2019	Zero waste goals and achievements as described by Nestle. Various reports focused on individual country markets. The 'Food Loss and Waste: Facts and Figures' reports (prepared by WWF) include data used to estimate GHG emissions.			https://www.nestle.c om/csv/impact/envir onment/waste-and- recovery
W	Zero Emissions Systems in Food Processing Industry Ngoc and Schnitzer, 2008	Outlook and principals of zero emissions systems.			https://pdfs.semantic scholar.org/31c0/e8d db0e45c4a6fac5ba6 052d0a422d612f06. pdf
X	Analysis of U.S. Food Waste Among Food Manufacturers, Retailers, and Restaurants BSR, 2013 for the Food Waste Alliance	Survey data of U.S. food manufacturers and retail establishments; includes data on food loss and amounts disposed	Relevant data include amount landfilled/incinerated for food manufacturers (1.1 MMT in 2011)	Executive summary, survey data extrapolated to U.S. for 2011	http://www.foodwast ealliance.org/wp- content/uploads/201 3/06/FWRA_BSR_Ti er2_FINAL.pdf

ID	Resource Title, Author, Year Published	Type and Quantity of Solid Waste Generated	Disposal Methods	Page Numbers	URL
Y	Wasted Food Measurement Methodology Scoping Memo EPA, 2020	EPA's scoping memo describes prior methodology and enhanced methodology that was developed between 2017 and 2019 to estimate the amount of sector-specific food waste, how much excess food/food waste was sent to separate management pathways, and the resulting food waste/management pathway estimates for 2016.	Management pathways for the industrial food waste sector discussed on pp. 24-25.	Industrial food waste tonnage discussed on p. 24.	https://www.epa.gov/ sites/default/files/202 0- 06/documents/food_ measurement_meth odology_scoping_m emo-6-18-20.pdf
Z	Advancing Sustainable Materials Management: 2018 Fact Sheet EPA, 2020	Analysis of U.S. municipal solid waste (MSW) trends in generation/management, materials/products, and economic indicators affecting MSW for 2018.			https://www.epa.gov/ sites/default/files/202 1- 01/documents/2018_ ff_fact_sheet_dec_2 020_fnl_508.pdf
AA	Advancing Sustainable Materials Management: 2018 Tables and Figures EPA, 2020	Supporting tables and figures for the Advancing Sustainable Materials Management: 2018 Fact Sheet.			https://www.epa.gov/ sites/default/files/202 1- 01/documents/2018_ tables_and_figures_ dec_2020_fnl_508.p df
AB	2018 Wasted Food Report EPA, 2020	EPA's sector-specific food waste estimations for 2018 using enhanced methodology as described in the EPA's Wasted Food Measurement Methodology Scoping Memo.	Management pathways of industrial food waste discussed on pp. 15-18.	Total industrial food waste generation in tpy/percent of total across all sectors discussed on pp. 13- 14.	https://www.epa.gov/ sites/default/files/202 0- 11/documents/2018_ wasted_food_report. pdf
AC	Making up for Lost Time (and Space): Quantifying Non-hazardous Industrial Waste Generation in the U.S. Final Report Prepared for the Environmental Research and Education Foundation (EREF) Krones, Chertow, and Li, 2020	Food, beverage, and tobacco sector solid waste estimations determined by using a combination of four individual estimation methods.		Estimated tonnages of food, beverage, and tobacco sector waste by NAICS code summarized on pp. 19-21.	https://erefdn.org/wp - content/uploads/202 1/01/EREF_Final- Report_NHIW_1216. pdf

ID	Resource Title, Author, Year Published	Type and Quantity of Solid Waste Generated	Disposal Methods	Page Numbers	URL

Appendix B. Key Search Terms

Key Search Terms	Related Report [ID]
Waste Disposal + Industrial Food Processing	А; В
Quantity of Waste Generated by Industrial Fruit Processing Plant	C; D
Amount of Waste Generated in Food Processing Industry	E
Food and Beverage + Waste	F
US Food Processing Waste + Landfills	G
Waste Management Techniques in Food Industry	H; I; J; K; L; M; N; O; P
Food Processing Industry and Waste Overview	Q; R
Food Losses and Waste	S
Overview of the Food Processing Industry in the US	Т
Zero Waste + Industrial Food Processing	U; V
Zero Waste + Food Processing Industry	W

Appendix C. Trade Organization Names

Trade Organization Names	Related Report [ID]
National Food Processors Association	Α
Wastecare Organization	В
World Bank Group	C
National Canners Association	D
CAST	F
Agricultural National Research Council	Q
Food and Agriculture Association of the United Nations	S
Institute of Medicine and National Research Council	Т
Food Waste Alliance	G (indirectly)

Addressing a Time Series Inconsistency in Federal Highway Administration Onroad Activity Data

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021: Addressing a Time Series Inconsistency in Federal Highway Administration Onroad Activity Data

This memo provides research and analyses to support improvements in the transportation and mobile source component of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* ("Inventory") annual report, detailing suggested changes to the onroad fuel consumption and vehicle miles traveled (VMT) data used in the Inventory. Currently, motor gasoline and diesel fuel consumption estimates for onroad vehicles by vehicle type come from Federal Highway Administration (FHWA) Highway Statistics Series¹ Table VM-1 table and are based on federal and state fuel tax records. These fuel consumption estimates are combined with estimates of fuel shares by vehicle type from Oak Ridge National Laboratory's Transportation Energy Data Book (TEDB)², to develop an estimate of fuel consumption for each vehicle type in the Inventory (i.e., passenger cars, light-duty trucks, buses, medium- and heavy-duty trucks, motorcycles). The onroad gasoline and diesel fuel consumption estimates by vehicle type are then adjusted for each year so that the sum of gasoline and diesel fuel consumption across all onroad vehicle categories match the fuel consumption estimates in Highway Statistics' Table MF-27. This results in a final "bottom-up" estimate of motor gasoline and diesel fuel use by vehicle type, consistent with FHWA data for onroad motor gasoline and diesel fuel use.

In 2011, FHWA changed its methods for estimating VMT and related data. These methodological changes included how vehicles are classified, moving from a system based on body-type to one that is based on wheelbase. These changes were first incorporated in the 1990 through 2008 Inventory and apply to the time series beginning in 2007. The FHWA methodology update resulted in large changes in VMT and fuel consumption by vehicle class, leading to a shift in emissions among onroad vehicle classes. For example, FHWA replaced the vehicle category "Passenger Cars" with "Light-duty Vehicles, Long Wheelbase" and the "Other 2 axle-4 Tire Vehicles" category was replaced by "Light-duty Vehicles, Long Wheelbase." FHWA changes to the definition of light-duty vehicles to less than 10,000 lbs. GVWR instead of 8,500 lbs. GVWR pushed some single-unit heavy-duty trucks to the light-duty class. This change in vehicle classification also moved some smaller trucks and sport utility vehicles from the light truck category to the passenger vehicle category in this Inventory. These updates resulted in a disconnect in FHWA VMT and fuel consumption data in the 2006-2007 timeframe, as shown by the large drop in the light-duty vehicle trend lines, as shown in Figures 1 and 2.

To address this inconsistency in the time series we propose dividing FHWA VMT data from Highway Statistics Table VM-1 into vehicle classes and fuels using distributions from EPA's Motor Vehicle Emission Simulator, MOVES³. The MOVES model is a nationally recognized mobile source emissions model based on vehicle registration data, travel activity, and emission rates that are updated with each model

¹ <u>https://www.fhwa.dot.gov/policyinformation/statistics.cfm</u>

² <u>https://tedb.ornl.gov/</u>

³ <u>https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves</u>

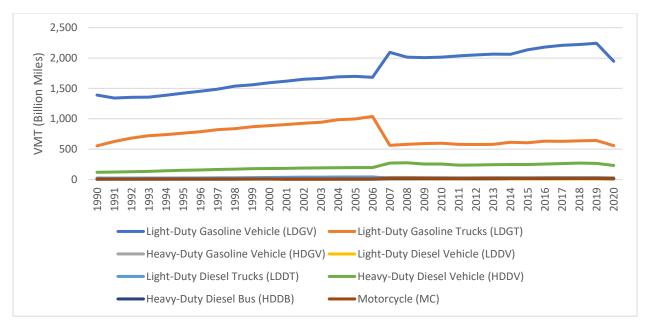


Figure 1. FHWA VMT by vehicle class. Source: FHWA Highway Statistics, Table MV-1.

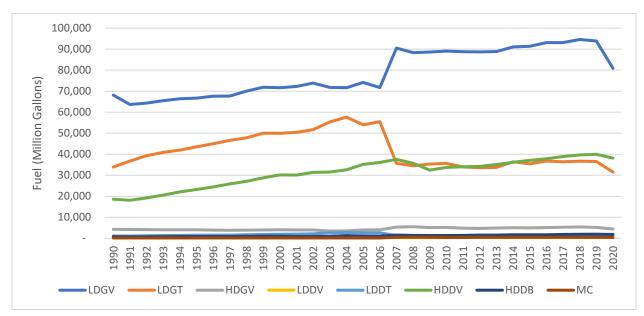


Figure 2. FHWA fuel consumption by vehicle class. Source: FHWA Highway Statistics, Table MF-21.

release. MOVES3 is the latest version of MOVES. Future emissions estimates are based on forecast growth factors which provide EPA's best estimate of likely future activity based on historical data. Thus, dividing FHWA total VMT data into vehicle class and fuel type using MOVES3 ratios would provide a more consistent estimate of onroad vehicle activity over the Inventory time series. MOVES3 ratios can also be used to reallocate FHWA gasoline and diesel fuel use data from (Highway Statistics Table MF-21).

In summary, we propose using onroad fuel consumption data from FHWA Table MF-21 to determine total onroad use of motor gasoline and diesel fuel. Ratios developed from MOVES3 output are then used to apportion FHWA fuel consumption data to vehicle type and fuel type. Similarly, we propose using FHWA Table VM-1 to determine total onroad VMT and employing ratios developed from MOVES3 output to apportion FHWA VMT data to vehicle and fuel types. We apply these ratios to 1990 through the present calendar year to remove the time series inconsistency caused by FHWA's vehicle classification methodology update.

MOVES Calculations

The MOVES3 model was run for calendar years 1990 and 1999 through 2020 for all onroad vehicle types. Calendar years 1991 through 1998 were linearly interpolated from 1990 and 1999 calendar year MOVES3 outputs. Model outputs of VMT and fuel consumed were binned by calendar year, MOVES vehicle source type, and fuel type. MOVES vehicle source types are matched to the vehicle types used in the Inventory per the mapping shown in Table 1. Only outputs of gasoline and diesel fuel consumption from MOVES3 were used; alternative fuel VMT and fuel consumption outputs are ignored because they are calculated for the Inventory under a separate methodology. Heavy-duty gasoline buses are included in the medium-and heavy-duty gasoline vehicle category. Diesel buses are broken out separately.

GHG Inventory Vehicle Category	MOVES Vehicle Source Type
Motorcycles	Motorcycle
Light-Duty Vehicles	Passenger Car
Light Duty Trucks	Passenger Truck
Light-Duty Trucks	Light Commercial Truck
	Intercity/Other Bus
Heavy-Duty Buses	Transit Bus
	School Bus
	Refuse Truck
	Single Unit Short-haul Truck
Medium- and Heavy-Duty Trucks	Single Unit Long-haul Truck
Medium- and heavy-Duty Trucks	Motor Home
	Combination Short-haul Truck
	Combination Long-haul Truck

Table 1. Mapping between MOVES vehicle source types and vehicle categories used in the Inventory

Ratios of vehicle type for each fuel were determined from the fuel consumption calculated by MOVES3 for calendar years 1990 and 1999 through 2020. A sample of these ratios is shown in Table 2. Calendar years 1991 through 1998 were interpolated from 1990 and 1999 data because MOVE3 does not generate output for these years.

	Calendar Year				
Vehicle Type	1990	2000	2010	2020	
MC	0.35%	0.40%	0.60%	0.71%	
LDGV	64.87%	50.03%	43.62%	35.39%	
LDGT	30.02%	46.25%	53.51%	61.03%	
HDGV	4.75%	3.33%	2.26%	2.87%	
Total Gasoline	100.00%	100.00%	100.00%	100.00%	
LDDV	4.33%	0.90%	0.55%	0.62%	
LDDT	3.87%	5.67%	7.55%	7.44%	
HDDT	86.72%	88.43%	88.04%	87.07%	
HDDB	5.08%	5.00%	3.86%	4.87%	
Total Diesel	100.00%	100.00%	100.00%	100.00%	

Table 2. MOVES3 gasoline and diesel fuel consumption ratios by vehicle type

Total onroad gasoline and diesel fuel consumption values from FHWA Table MF-21 were then allocated to Inventory vehicle types using the MOVES3 ratios in Table 2. Sample results are show in Table 3.

	Fuel Consumed (1000 gallons)					
Vehicle Type	1990	2000	2010	2020		
MC	388,591	512,923	798,430	829,861		
LDGV	71,047,691	64,563,117	58,337,579	41,493,067		
LDGT	32,878,948	59,686,281	71,561,833	71,557,342		
HDGV	5,205,564	4,298,732	3,027,419	3,370,758		
Total Gasoline	109,520,794	129,061,053	133,725,262	117,251,028		
LDDV	920,907	301,346	200,169	260,648		
LDDT	821,822	1,899,736	2,770,707	3,117,895		
HDDT	18,423,336	29,618,750	32,297,960	36,511,115		
HDDB	1,078,861	1,673,278	1,416,453	2,043,802		
Total Diesel	21,244,926	33,493,110	36,685,289	41,933,460		

Table 3. Gasoline and diesel fuel consumption from FHWA MF-21 allocated to vehicle type using MOVES3 ratios

MOVES3 was also used to calculate VMT by vehicle class and fuel type for calendar years 1990 and 1999 through 2020. A sample of these ratios is shown in Table 4.

	Calendar Year							
Vehicle Type	1990	2000	2010	2020				
MC	0.53%	0.44%	0.62%	0.63%				
LDGV	67.85%	53.42%	46.89%	37.73%				
LDGT	19.95%	34.21%	40.54%	49.24%				
HDGV	2.07%	1.54%	1.04%	0.91%				
LDDV	1.90%	0.45%	0.23%	0.27%				
LDDT	0.92%	1.44%	1.63%	2.09%				
HDDT	6.38%	8.02%	8.65%	8.66%				
HDDB	0.39%	0.47%	0.40%	0.47%				
Total VMT	100.00%	100.00%	100.00%	100.00%				

Table 4. MOVES3 VMT ratios by vehicle and fuel type

VMT by vehicle type and fuel type was then calculated by multiplying the total VMT from FHWA Table VM-1 by the MOVES3 ratios in Table 4. The resulting VMT by vehicle type and fuel type is shown in Table 5.

	VMT (million miles)							
Vehicle Type	1990	2000	2010	2020				
MC	11,401	12,176	18,528	18,200				
LDGV	1,455,053	1,467,289	1,391,321	1,094,899				
LDGT	427,748	939,822	1,202,919	1,434,743				
HDGV	44,425	42,403	30,855	26,177				
LDDV	40,838	12,474	6,825	7,900				
LDDT	19,806	39,434	48,258	57,456				
HDDT	136,780	220,299	256,611	250,676				
HDDB	8,311	13,028	11,948	13,571				

Table 5. VMT from FHWA Table VM-1 allocated to vehicle type using MOVES3 ratios

The revised time series of fuel consumption and VMT are shown in Figure 3 and Figure 4, respectively. As can be seen from these figures, the 2006-2007 discontinuities highlighted in the above discussion and illustrated in Figure 1 and Figure 2 are corrected, and the curves now demonstrate the increased VMT and fuel consumption of SUVs and light trucks (i.e., LDGT) overtaking that of cars (i.e., LDGV).

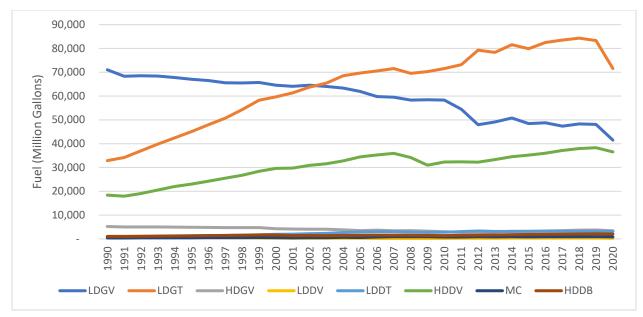


Figure 3. Revised fuel consumption incorporating the updated methodology based on MOVES3 ratios.

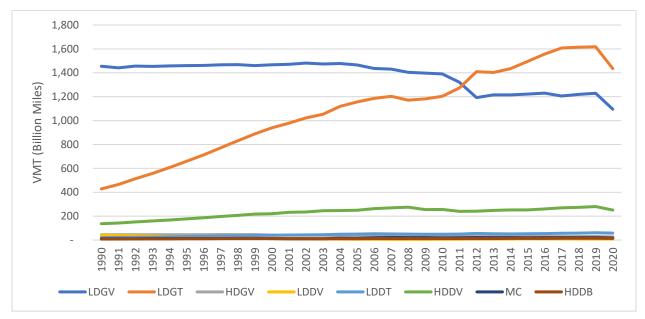


Figure 4. Revised VMT incorporating the updated methodology based on MOVES3 ratios.

Discussion

As a check of the reasonableness of the proposed updated approach, fuel economy in miles per gallon (mpg) were calculated for the MOVES-adjusted data and compared against mpg calculated from MOVES output and mpg calculated from FHWA data. As can be seen in Table 6, the MOVES-adjusted mpg is close to values generated by MOVES, but differs from the mpg generated directly from FHWA data.

	2010			2015			2020			
Vehicle Categories	MOVES Adjusted	MOVES	FHWA	MOVES Adjusted	MOVES	FHWA	MOVES Adjusted	MOVES	FHWA	
LDGV	23.85	23.76	22.62	25.25	24.81	23.39	25.73	27.52	24.07	
LDGT	16.81	16.91	16.78	18.72	18.18	17.14	19.55	20.39	17.71	
HDGV	10.19	12.64	6.24	8.94	10.72	6.35	7.57	7.59	6.64	
LDDV	34.10	26.84	27.52	32.78	29.30	24.88	29.55	30.08	22.14	
LDDT	17.42	13.71	20.42	16.53	14.78	18.23	17.97	18.29	16.29	
HDDV	7.95	6.25	7.55	7.18	6.42	6.71	6.69	6.81	6.07	
HDDB	8.44	6.64	9.83	7.32	6.55	8.89	6.47	6.59	7.82	
MC	23.21	23.12	42.04	23.39	22.98	42.91	21.38	22.87	43.85	

Table 5. Comparison of calculated fuel economy (mpg)

It is notable that because of the Corporate Average Fuel Economy (CAFE) federal emissions standards, LDGV mpg is better than that of motorcycles in MOVES3. This is most likely due to the use of hybrid vehicles, which increase fleet mpg. Motorcycles are exempt from CAFE standards.

Per Figure 4 above, the adjusted VMT time series shows light-duty truck VMT exceed light-duty vehicle VMT in 2012. Light-duty truck gasoline consumption exceeds light-duty vehicle gasoline consumption in 2003. Note that using different data sources can produce different results. For instance, the Transportation Energy Data Book (TEDB) reports that light-duty truck fuel consumption (measured in BTUs) did not exceed that of cars until 2010. However, the TEDB analysis appears to rely on FHWA's vehicle definitions, which are based on wheelbase and include some small pickup trucks and SUVs in the passenger car category. Using the same FHWA vehicle categories, the TEDB also reports that the share of light-duty truck VMT did not exceed passenger cars until 2017. It is important to highlight that federal agencies have differing definitions for the term "light truck", as do private sector data services.

Emissions Impacts

The proposed updates to the fuel consumption and VMT data used in the onroad transportation component of the Inventory result in updated emissions across the time series. Overall, because total fuel consumption and VMT values are conserved, the changes in total emissions are small, within 0.1%. Table 6 provides a summary of the magnitude of changes in total emissions. Observed differences are due to changes in onroad CH₄ and N₂O emissions, as the methodology for calculating these non-CO₂ emissions utilizes more detailed activity data and is therefore sensitive to the re-allocation of activity data inherent in the proposed update. Total CO₂ emissions and CH₄ and N₂O emissions from nonroad sources remain the same.

Year	Original Estimate	Revised Estimate	Percent Change
1990	1,696.90	1,695.40	-0.09%
2000	2,096.60	2,096.80	0.01%
2010	2,012.80	2,014.60	0.09%
2011	1,977.00	1,979.00	0.10%
2012	1,957.20	1,959.20	0.10%
2013	1,962.10	1,963.80	0.09%
2014	1,993.30	1,994.80	0.08%
2015	1,990.40	1,991.60	0.06%
2016	2,027.80	2,028.90	0.05%
2017	2,051.60	2,052.60	0.05%
2018	2,087.10	2,088.00	0.04%
2019	2,092.70	2,092.30	-0.02%
2020	1,831.70	1,832.40	0.04%

Table 6. Changes in total U.S. greenhouse gas emissions from transportation and mobile sources (MMT CO2 Eq.)	Table 6. Changes in total U.S. greenhouse gas emissions from	m transportation and mobile sources (MMT CO2 Eq.)
--	--	---

While total emissions estimates (Table 6) are not significantly impacted by this methodology update, there are significant changes in the allocation of emissions by vehicle type. The share of emissions allocated to passenger cars generally decline through the time series while the share of emissions allocated to lightduty trucks increase. These trends are in accordance with the revised fuel consumption trends shown in Figure 3.

Year	Passeng	er Cars	Light-Duty Trucks		Medium- and Heavy-Duty Trucks		Buses		Motorcycles	
	Original	Revised	Original	Revised	Original	Original Revised		Revised	Original	Revised
1990	639.6	651.1	326.7	303.5	230.3	234.4	8.5	13.3	1.7	3.4
2000	685.8	607.2	506.7	580.2	352.3	347.3	11.1	19.2	1.9	4.4
2001	687.9	600.1	509.6	592.7	350.5	347.5	10.3	16.2	1.7	4.1
2002	700.5	603.1	521.9	616.5	364.6	358.8	10.0	17.0	1.7	4.1
2003	687.7	601.6	563.6	637.3	362.1	366.9	10.8	16.8	1.6	4.3
2004	677.4	587.8	579.4	660.1	373.5	377.0	15.3	17.8	1.7	5.5
2005	691.7	569.0	537.7	664.4	404.1	391.8	12.3	17.9	1.6	5.0
2006	668.7	549.3	553.3	674.7	413.7	401.0	12.5	18.8	1.9	6.9
2007	824.3	540.3	359.4	676.0	438.1	403.7	18.0	19.2	4.2	7.6
2008	778.5	512.2	338.4	636.4	420.7	387.0	17.5	18.8	4.3	7.2
2009	774.0	508.8	343.5	637.9	379.8	348.3	16.2	17.8	4.2	7.2
2010	762.7	497.3	339.6	636.6	393.5	359.9	16.0	17.4	3.6	6.4
2011	753.3	461.4	322.6	646.9	387.5	353.0	16.6	18.2	3.6	6.3

Table 7. Changes in U.S. Greenhouse Gas Emissions by Vehicle Type (MMT CO2 Eq.)

Year	Passeng	er Cars	Light-Du Trucks	ıty	Medium Heavy-D Trucks		Buses		Motorcy	/cles
2012	746.2	403.9	316.0	692.6	388.7 352.1 2		17.7	19.3	4.1	7.1
2013	739.2	407.5	312.1	675.8	393.0	358.1	17.8	19.7	3.9	6.8
2014	753.0	417.9	331.9	696.8	406.1	372.5	19.2	21.4	3.9	7.0
2015	752.6	407.3	320.9	696.1	413.4	378.8	19.5	22.4	3.7	6.8
2016	763.2	407.8	330.0	713.6	416.8	383.0	19.0	22.5	3.9	7.2
2017	760.6	394.1	324.3	718.6	429.7	396.1	20.5	23.9	3.8	7.2
2018	770.2	399.9	325.6	722.8	440.0	407.2	21.8	24.8	3.9	7.4
2019	763.1	396.5	323.7	714.0	439.5	410.0	21.7	25.3	3.7	7.5
2020	617.7	343.0	315.8	617.4	422.8	387.4	18.0	23.9	3.3	6.7

Under the original methodology, the change in FHWA's methodology for vehicle classification caused a sharp rise in the emission estimates from passenger cars in 2006-2007 (see Figure 5). With the revised methodology, this inconsistency in the time-series is removed (see Figure 6). Passenger car emission estimates are gradually decreasing, while light-duty truck emissions are gradually increasing over the time series.

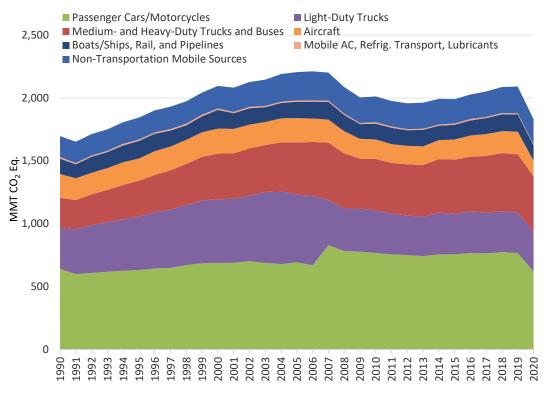


Figure 5. Original (unadjusted) domestic greenhouse gas emissions by mode and vehicle type, 1990-2020⁴.

⁴ As reported in Annex 3 of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020* report: <u>https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-annex-3-additional-source-or-sink-categories-part-a.pdf</u>

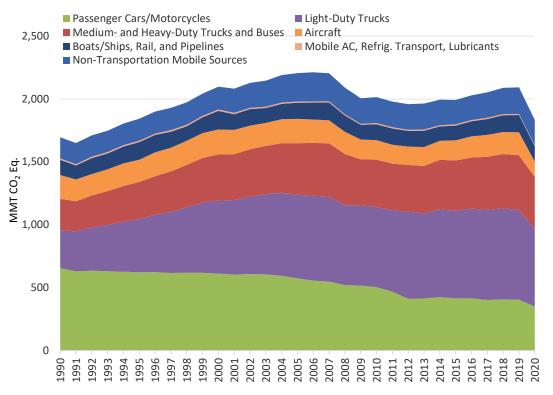


Figure 6. Revised domestic greenhouse gas emissions by mode and vehicle type, 1990-2020.

Proposed Methodological Refinements for Glass Production

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021

Proposed Methodological Refinements for Glass Production

Note: This memo was updated from the version shared during expert review to clarify information, consistent with the final national greenhouse gas inventory. Updates are noted in footnotes.

1 Background

EPA has researched and is proposing methodological refinements to estimate process CO₂ emissions (i.e. calcination-related) from the Glass Production source category included in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI), based on data from the Greenhouse Gas Reporting Program (GHGRP) for other carbonates used in glass production consistent with the *2006 IPCC Guidelines*.¹ EPA conducted analyses during the 1990 to 2021 GHGI cycle to integrate data on a group of other carbonates: barium carbonate, lithium carbonate, potassium carbonate, and strontium carbonate. This memorandum outlines proposed methodological improvements to integrate these data and also includes preliminary national estimates reflecting improvements. The process CO₂ emissions from glass production are reported in section 4.3 of the GHGI, and full time series data will be reported under Category 2A3 in the Common Report Format (CRF) table reporting. Emissions from fuel used for energy at glass production facilities are already included in the overall industrial sector energy use (as obtained from the Energy Information Administration (EIA)) and accounted for as part of energy sector emissions in Chapter 3 the Inventory. This memo focuses on methods to account for process-related CO₂ emissions from glass production.

Several carbonates are used in glass production, including limestone, dolomite, soda ash, and other carbonates (in smaller quantities). Carbon dioxide emissions are calculated based on the 2006 IPCC *Guidelines* Tier 3 method by multiplying the mass of carbonate used by the carbonate-based mineral mass fraction and an emissions factor for each carbonate.

2 Current National GHGI Methodology (1990-2020 GHGI)

Process-related CO₂ emissions under the current methodology are calculated based on the 2006 IPCC Guidelines Tier 3 method by multiplying the quantity of carbonates (i.e., limestone, dolomite, soda ash) by the IPCC default carbonate-based emission factor in metric tons CO_2 /metric ton carbonate (i.e., limestone, 0.43971; dolomite, 0.47732; soda ash, 0.41492)², and by the average carbonate-based mineral mass fraction for each year from GHGRP for limestone and dolomite. This methodology continues to assume that soda ash contains 100 percent sodium carbonate (Na₂CO₃), and that the calcination fraction is 1.0, both consistent with 2006 IPCC Guidelines.

To account for time series consistency, EPA uses 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.

¹ 2006 IPCC Guidelines, Volume 3 Industrial Processes and Product Use, Chapter 2 Mineral Industry Emissions, Section 2.4 Glass Production.

² 2006 IPCC Guidelines, Volume 3 Industrial Processes and Product Use, Chapter 2 Mineral Industry Emissions, Section 2.1 Introduction.

2.1 Methodology for 2010 through 2020

The methodology for estimating process CO₂ emissions from glass production for years 2010 through 2020 uses activity data on the quantities of soda ash used for glass production from USGS and the quantities of limestone and dolomite used for glass production reported to the GHGRP.

EPA uses USGS data on soda ash consumption because it is more complete than the GHGRP data, due to the 100 percent response rate from soda ash companies to USGS surveys (USGS 1995 through 2015b), USGS not having a reporting threshold, and the availability of USGS data on soda ash consumption by end-use and glass production in particular. For 1990 through 2020, 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 (2017 through 2021) (USGS 2017 through 2021).

Glass production facilities with greenhouse gas emissions greater than 25,000 metric tons CO₂e report data to GHGRP annually. The reporting threshold is used to provide comprehensive coverage of GHG emissions, targeting large industrial emitters and suppliers while minimizing the burden on smaller facilities. Smaller facilities below this threshold have not been accounted for yet for this portion of the time series.³ 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 2022). 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."

For 2010 through 2020, EPA calculated the metric tons of process emissions resulting from glass production by multiplying the mass of carbonate used in glass manufacturing (i.e., limestone, dolomite, soda ash) by the average carbonate-based mineral mass fraction for each year and also by the IPCC default carbonate-based emission factor (in metric tons CO₂/metric ton carbonate): limestone, 0.43971; dolomite, 0.47732; and soda ash, 0.41492.

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 (CaCO₃); dolomite contained 98.5 percent calcium magnesium carbonate (CaMg(CO₃)₂); and soda ash contained 99.2 percent sodium carbonate (Na₂CO₃). 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 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 CO₂e in process emissions from glass production (EPA 2009). By setting the reporting threshold at 25,000 metric tons CO₂e, facility coverage was estimated at 14.7% (55 facilities) and emissions coverage was estimated at 50.7% (0.84 million metric tons CO₂e). 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 CO₂e. Because EPA received data from more facilities than expected and higher reported total emissions than previously estimated in the technical support document for all glass production facilities in the United States in 2010 and in subsequent years, EPA will need to reassess the completeness of the reported GHGRP data and this will require additional work, starting with a review of latest data on glass production in the United States.

The methodology for 1990-2020 continued to assume that soda ash contains 100 percent sodium carbonate (Na₂CO₃), consistent with *2006 IPCC Guidelines*, instead of using the GHGRP data.

2.2 Methodology for 1990 through 2009

Data from GHGRP on the quantity of limestone and dolomite used in glass production and on the average carbonate-based mineral mass fractions are not available for 1990 through 2009; facilities began reporting to GHGRP for the year 2010. Analysis completed for the previous GHGI on the USGS and GHGRP datasets showed an inconsistent overlap between the USGS and GHGRP data for 2010 to 2021.

To address this time series consistency issue, 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 2022).

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 2022). The monthly index values for each year were averaged to calculate an average annual glass production index value. Total annual process emissions were calculated by taking a ratio of the average annual glass production index for base year 2017 and multiplying by the calculated 2017 emissions (process-related) based on GHGRP data (see Equation 1).

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

where:

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

Process emissions from the consumption of limestone and dolomite were disaggregated from estimated total annual emissions, using the average percent contribution of each to the sum of GHGRP emissions from limestone and dolomite for 2010 through 2020: 62.9 percent limestone and 37.1 percent dolomite.

3 Proposed National GHGI Methodological Refinements

3.1 Incorporating GHGRP "Other Carbonates" Data for 2010 and Onward

The proposed refinement for estimating process CO₂ emissions from glass production for years 2010 through 2021 incorporates additional new activity data on the quantities of a group of other carbonates

(i.e., barium carbonate, potassium carbonate, lithium carbonate, and strontium carbonate) used for glass production reported to the GHGRP. This refinement improves the completeness and accuracy of the methodology. The methodology continues to use the GHGRP quantities of limestone and dolomite and USGS quantities of soda ash. The proposed refinement also incorporates the average carbonate-based mineral mass fraction for soda ash from the GHGRP to improve methodology consistency for all carbonates.

GHGRP collects data from glass production facilities with greenhouse gas emissions greater than 25,000 metric tons CO_2e . Smaller facilities below this threshold have not been accounted for yet in the 2010 to 2021 portion of the time series.⁴

Using the total quantities of the group of other carbonates ("other carbonates") for years 2010 through 2021, EPA calculated the metric tons of emissions resulting from glass production by multiplying the quantity of other carbonates by the average carbonate-based mineral mass fraction for other carbonates for each year and also by the average emission factor (in metric tons CO₂/metric ton carbonate) of 0.262 for other carbonates, calculated from GHGRP data.⁵ For each year starting in 2010, the average carbonate-based mineral mass fraction for other carbonates was calculated using the weighted average carbonate-based mineral mass fraction for each of the four carbonates in the group of other carbonates.

The average carbonate content of glass production inputs, based on GHGRP data between 2010 and 2014, are shown in **Table 1**. 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."

The average carbonate-based mineral mass fraction for soda ash from the GHGRP, averaged across 2010 through 2021, indicated that the soda ash contained 99.0 percent sodium carbonate (Na_2CO_3), while the data averaged across 2010 through 2014 indicated that the soda ash contained 98.7 percent Na_2CO_3 . The years 2010 to 2014 were used to determine the average carbonate-based mineral mass fractions because that period was deemed to better represent historic glass production from 1990 to 2009.⁶

⁴ See footnote 3 on previous page.

⁵ Expert Judgement form entitled "Draft Glass GHGI Expert Judgement Form_Other

Carbonate_Emission_Factor_November_2022.docx"

⁶ Between expert review and publication of the final national greenhouse gas inventory, the proposed methodological refinement was revised to average GHGRP data for the years 2010 to 2014 to be more representative of historic glass production.

	Carbonate Mineral Content for Glass Production						
Carbonate	1990-2019 GHGI Assumptions^	GHGRP Data,					
	(IPCC default values)	2010-2014 Average ⁷					
Limestone, CaCO ₃	100%	97.9%*					
Dolomite, CaMg(CO ₃) ₂	100%	98.0%*					
Soda Ash, Na ₂ CO ₃	100%	98.7%*					
Other carbonates	Not Available	99.8%*					

Table 1. Carbonate mineral content of carbonates used for glass production.

* GHGRP data on carbonate mineral content of limestone, dolomite, and soda ash used for glass production are averaged for the years 2010 through 2014 and used to calculate emissions from 1990 through 2009. Emissions calculations used unique values for each year starting with 2010.

^ Methodological refinements for glass production were implemented over two inventory cycles beginning in the 1990-2020 GHGI. The 1990-2019 GHGI was the last inventory that used the IPCC default carbonate mineral content values.

3.2 Time Series Considerations and Back-casting for 1990 through 2009

Data from GHGRP on the quantity of other carbonates used in glass production and on the average carbonate-based mineral mass fractions are not available for 1990 through 2009; facilities began reporting to GHGRP for the year 2010. Additionally, USGS does not collect data on the quantity of other carbonates used for glass production. EPA proposes updating the current back-casting methodology (described in Section 2.2) to integrate other carbonates.

The current methodology disaggregates emissions from the consumption of limestone and dolomite from estimated total annual emissions by using the average percent contribution of each to total GHGRP emissions from limestone and dolomite. The proposed improvement would expand this approach to include other carbonates, disaggregating emissions from the consumption of limestone, dolomite, and other carbonates from estimated total annual emissions by using the average percent contribution of each to total GHGRP emissions from limestone, dolomite, and other carbonates for estimated total annual emissions by using the average percent contribution of each to total GHGRP emissions from limestone, dolomite, and other carbonates for 2010 through 2014: 64.5 percent limestone, 35.5 percent dolomite, and 0.1 percent other carbonates. See **Table 2** for a comparison of these values and the values used in the previous GHGI.

The proposed methodology assumes that soda ash contains 98.7 percent Na₂CO₃, consistent with the average mass fraction in the GHGRP from 2010 through 2014.

⁷ Between expert review and publication of the final national greenhouse gas inventory, the GHGRP column in Table 1 was updated with averages of GHGRP data spanning 2010 to 2014 for consistency with the final methodological refinement.

Table 2. Average Contribution of Limestone, Dolomite, and Other Carbonates Relative to TotalEmissions from These Carbonates, Used to Back-Cast and Disaggregate Total Emissions for 1990-2009

Carbonate	Average percent contribution of each carbonate to total GHGRP emissio for 2010 through 2014						
	Previous Inventory	Proposed Refinements ⁸					
Limestone	62.9%	64.5%*					
Dolomite	37.1%	35.5%*					
Other carbonates	Not Applicable	0.1%*					

4 Preliminary Emissions Estimates

Overall, the proposed methodological refinements led to minor changes in emissions for 2010 through 2021 and a reallocation of emissions for 1990 through 2009 from the Glass Production source category, compared to the current methodology (see **Table 3**). The observed changes in emissions are due to the addition of the group of other carbonates used to produce glass and also some newly available data to be used for recalculations.

Table 3. Emissions estimates using the current and proposed methodologies (kt CO_2e)⁹

Methodologies	1990	2005	2016	2017	2018	2019	2020
Methodology for	2,291	2,432	2,119	2,011	1,989	1,938	1,857
1990-2020 GHGI							
Proposed refinement	2,263*	2,402	2,118	1,984	1,989	1,940	1,858
Difference (kt)	-28	-30	-1	-27	0	2	1

* Due to a transcription error, this 1990 emission value is not reflected in Tables 4-12 and 4-13 of the 1990-2021 GHGI. The 1990 emissions value will be revised in the 1990-2022 GHGI.

5 Planned Improvements

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 CO₂e encompassing 50.7 percent of total emissions.¹⁰

⁸ Between expert review and publication of the final national greenhouse gas inventory, the proposed refinements column in Table 2 was updated using averages of GHGRP data spanning 2010 to 2014 for consistency with the final methodological refinement.

⁹ Between expert review and publication of the final national greenhouse gas inventory, the proposed refinements row in Table 3 was updated for consistency with the final methodological refinement.

¹⁰ For the previous assessment, see *Technical Support Document for the Glass Manufacturing Sector: Proposed Rule for Mandatory Reporting of Greenhouse Gases*, available here: <u>https://www.epa.gov/ghgreporting/subpart-n-technical-support-document</u>.

6 Request for Feedback

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

- EPA proposes to disaggregate emissions from the consumption of limestone, dolomite, and other carbonates from estimated total annual emissions for 1990 through 2009 by using the average percent contribution of each to total GHGRP emissions from limestone, dolomite, and other carbonates for 2010 through 2014 (see **Table 2**). Is the 2010 through 2014time period a reasonable representation of glass production taking place between 1990 and 2009?
- 2. EPA uses data from GHGRP starting in 2010 and the Federal Reserve Industrial Production index for the full time series to calculate emissions and quantities of carbonates used for glass production for the years 1990 to 2009. Please provide any recommendations to improve the transparency, accuracy, consistency, and/or completeness of the estimation methods.
- 3. Please provide feedback on the use of USGS data on soda ash used for glass production.
- 4. Please provide recommendations for any information that could be added to the discussion to provide additional transparency and clarity.

7 References

EPA (2009) Technical Support Document for the Glass Manufacturing Sector: Proposed Rule for Mandatory Reporting of Greenhouse Gases. U.S. Environmental Protection Agency, Washington, D.C.

EPA (2022) Greenhouse Gas Reporting Program (GHGRP). Aggregation of Reported Facility Level Data under Subpart N for Calendar Years 2010 through 2021. Office of Air and Radiation, Office of Atmospheric Programs, U.S. Environmental Protection Agency, Washington, D.C.

Federal Reserve (2022) Board of Governors of the Federal Reserve System (US), Industrial Production: Manufacturing: Durable Goods: Glass and Glass Product (NAICS = 3272) [IPG3272N], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/IPG3272N, September 30, 2022.

U.S. Bureau of Mines (1991 and 1993a) Minerals Yearbook: Crushed Stone Annual Report. U.S. Department of the Interior. Washington, D.C.

United States Geological Survey (USGS) (2017) Minerals Industry Surveys; Soda Ash in January 2017. U.S. Geological Survey, Reston, VA. March 2017.

USGS (2018) Mineral Industry Surveys: Soda Ash in February 2018. U.S. Geological Survey, Reston, VA. Accessed September 2018.

USGS (2019) Mineral Industry Surveys: Soda Ash in December 2018. U.S. Geological Survey, Reston, VA. Accessed September 24, 2019.

USGS (2020) Mineral Industry Surveys: Soda Ash in April 2020. U.S. Geological Survey, Reston, VA. Accessed November 2020.

USGS (2021) Mineral Industry Surveys: Soda Ash in April 2021. U.S. Geological Survey, Reston, VA. Accessed September 2021.

USGS (1995 through 2016a) Minerals Yearbook: Crushed Stone Annual Report. U.S. Geological Survey, Reston, VA.

USGS (1995 through 2015b) Minerals Yearbook: Soda Ash Annual Report. U.S. Geological Survey, Reston, VA.

USGS (2020a) Minerals Yearbook: Crushed Stone Annual Report: Advanced Data Release of the 2017 Annual Tables. U.S. Geological Survey, Reston, VA. August 2020. **Updates for Ammonia Production Emissions**

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021: Updates for Ammonia Production Emissions

1 Previous GHGI Methodology

Greenhouse gas emissions (CO₂, process and energy related) from ammonia production are currently described in Section 4.5 of the National Inventory Report (NIR) and reported under Category 2B1 in the Common Reporting Format (CRF) table reporting.

The existing methodology involves determining total ammonia production in the U.S. and then splitting that production between ammonia production from natural gas feedstock and ammonia production from petroleum coke feedstock. There is only one facility in the US that produces ammonia from petroleum coke (the Coffeyville Resources facility in Coffeyville, KS). Petroleum coke production data are taken directly from facility information either through company reports (10-K report) or from reporting to the Greenhouse Gas Reporting Program (GHGRP). Process emissions from ammonia produced from petroleum coke are also based on facility data and GHGRP reporting. The EPA is not proposing any changes to the treatment of ammonia from petroleum coke production.

Process CO₂ emissions from ammonia (NH₃) produced from natural gas are currently based on a country-specific approach of multiplying ammonia production data by an emission factor of 1.2 metric tons CO₂/metric ton NH₃ produced, which is published by the European Fertilizer Manufacturers Association (EFMA)¹. The factor is based on emissions from natural gas feedstock only; it does not account for natural gas used as a fuel in the process (e.g., for heating, etc.). Emissions from fuel used for energy at ammonia plants are included in the overall industrial sector energy use (as obtained from the Energy Information Administration (EIA)) and accounted for as part of energy sector emissions in Chapter 3 of the Inventory (See https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-3-energy.pdf)).

Process emissions of CO₂ from ammonia production are then adjusted to account for some of the CO₂ produced from ammonia production being used as a raw material in the production of urea. The process CO₂ emissions reported for ammonia production are reduced by a factor of 0.733 multiplied by total annual domestic urea production. This corresponds to a stoichiometric CO₂/urea factor of 44/60, assuming complete conversion of NH₃ and CO₂ to urea. The EPA is not proposing any changes to the adjustment of CO₂ emissions from ammonia production that are associated with urea production.

2 Background

The EPA is proposing updates to determine CO_2 emissions from ammonia produced from natural gas. The updates will address the following:

- Emissions will be based on quantity of natural gas used in the process as opposed to a CO₂ emission factor applied to production.
- The emissions will take into account emissions and feedstock information reported to the GHGRP on ammonia production.

¹ Best Available Techniques for Pollution Prevention and Control in the European Fertilizer Industry. Booklet No. 1 of 8: Production of Ammonium.

• The updated methodology will consider emissions from both feedstock and fuel natural gas use, in line with IPCC guidance². If this approach were taken, emissions from fuel use currently reported as part of energy sector emissions in Chapter 3 of the Inventory would no longer be reported there, but would be reallocated to Chapter 4 (IPPU) to avoid double counting fuel use emissions from ammonia production. This approach would allocate the emissions across sectors as prescribed in the 2006 IPCC Guidelines.

3 Available Data

EPA reviewed multiple data sources to identify relevant emissions and activity data. The data sources are provided along with a brief summary.

3.1 Ammonia Production and GHG Emissions

Ammonia production data are used in the current process to determine emissions. They are also needed in the proposed updated approach to apply GHGRP calculated factors across the entire time series. The current Inventory collects data on ammonia production over the time series from a number of sources including the American Chemistry Council (ACC) and the Census Bureau of the U.S. Department of Commerce.

As described above (in Section 1), the amount of ammonia production from petroleum coke will continue to use the current approach, and therefore the main focus of the update is on ammonia production from natural gas. Available GHGRP data include the amount of ammonia produced as well as GHG emissions. The ammonia production data in GHGRP are assumed to cover 100% of ammonia CO₂ emissions as documented in the ammonia technical support document to the GHGRP rule³. GHGRP reporting is based on ammonia facilities that emit GHG emissions through the steam reforming process; the brine electrolysis process for production of ammonia does not lead to process-based CO₂ emissions. Therefore, ammonia production data reported under GHGRP might be lower than overall ammonia production depending on the amount of ammonia produced through the brine electrolysis process.

Figure 1 shows the comparison of GHGRP ammonia production from natural gas and CO₂ emissions with what is currently used and reported in the Inventory. Note: for this figure, both the Inventory and the GHGRP data excludes production and emissions associated with petroleum coke ammonia production by excluding data from the Coffeyville Resources facility in Coffeyville, KS.

² Per 2006 IPCC Guidance: "in the case of ammonia production no distinction is made between fuel and feedstock emissions with all emissions accounted for in the IPPU Sector".

³ See Table 3 in <u>https://www.epa.gov/sites/default/files/2015-02/documents/ti_g-tsd_ammonia_epa_1-22-09.pdf</u>.

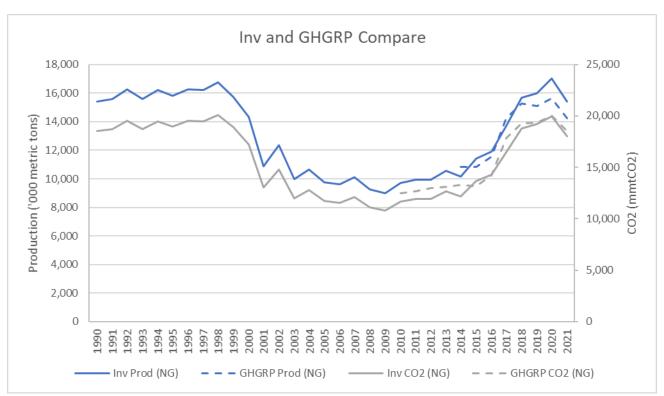


Figure 1: Comparison of Current Inventory and GHGRP Data

The GHGRP started collecting GHG data in 2010 and ammonia production data in 2014. The GHGRP data are consistent with existing Inventory data over the available time series. In more recent years, the GHGRP reports slightly less production compared to the Inventory. In earlier years the GHGRP reports slightly more CO₂ emissions than the Inventory.

The GHGRP emissions data are based on Subpart G reporting which includes:

• CO₂ process emissions from steam reforming of a hydrocarbon or the gasification of solid and liquid raw material, reported for each ammonia manufacturing process unit (Note: CO₂ process emissions include CO₂ that is later consumed on site for urea production).

GHG emissions from stationary fuel combustion units are reported under subpart C (General Stationary Fuel Combustion Sources) and are discussed later.

3.2 Natural Gas Feedstock Use

Starting in 2017, GHGRP facilities report the amount of feedstock used in the process under subpart G in terms of standard cubic feet (scf) of natural gas. Other data sources exist for feedstock natural gas used in the ammonia production process over time, including:

 As determined from current Inventory, the total calculated CO₂ emissions from natural gas ammonia production (before adjusting for urea) are converted to natural gas feedstock energy use based on the variable CO₂ emissions factors for natural gas used in the Inventory. They can be converted to scf based on variable heating content values from the Inventory as well.

- Based on the stoichiometric value of natural gas needed to produce the assumed amount of ammonia produced (0.414 kg CH₄ / kg NH₃) converted to C and then converted to scf based on the C emissions factors and heating content values used in the Inventory.
- From EIA Manufacturing Energy Consumption Survey (MECS) data for non-fuel use of natural gas in ammonia production. Data are only available for some years as the survey is only done every 4 years and some years are withheld for confidentiality reasons.
- Facility-reported data starting in 2017 under subpart G of the GHGRP for feedstock use (in scf).
- Data derived from the GHGRP reported CO₂ emissions, converted to scf based on average GHGRP reported values for C content and calculated molecular weights.

Figure 2 shows the comparison of the different data sources on feedstock use over time.

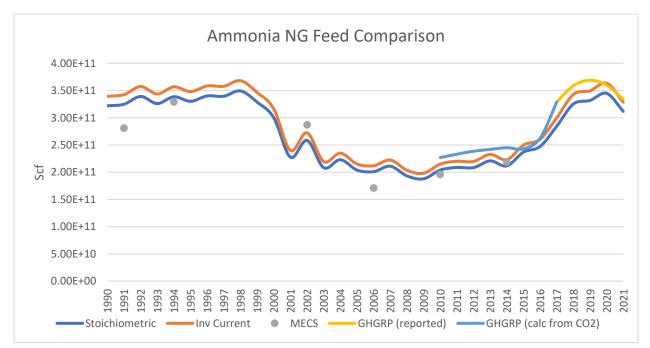


Figure 2: Comparison of NG Ammonia Feedstock Values

The current Inventory data are consistent with trends in the production data because the Inventory results are based on the assumed CO_2 emissions factor which is linked to production. It implies there is some natural gas feedstock used beyond the stoichiometric amount needed due to losses/efficiencies, etc.

The EIA MECS data are limited in coverage and for some years is below the stoichiometric quantity of feedstock needed. Differences over time could be due to coverage of the survey data. The data are reported for NAICS code 325311 Nitrogenous Fertilizers.

As noted, starting in 2017, GHGRP collects data on feedstock natural gas used for ammonia production. GHGRP also has data on CO₂ emissions associated with ammonia production starting in 2010 (which can be split between feedstock type by subtracting emissions associated with the one facility using petroleum coke). The GHGRP CO₂ emissions associated with natural gas feedstock use are calculated based on the following Equation 1: Equation 1: Calculation of CO₂ Emissions from NG Feedstock in GHGRP

$$CO_{2,G,k} = \left(\sum_{n=1}^{12} \frac{44}{12} * Fdstk_{n,k} * CC_n * \frac{MW}{MVC}\right) * 0.001$$
 (Eq. G-1)

Where:

 $CO_{2,G,k}$ = Annual CO_2 emissions arising from gaseous feedstock consumption (metric tons).

 $Fdstk_n$ = Volume of the gaseous feedstock used in month n (scf of feedstock).

 CC_n = Carbon content of the gaseous feedstock, for month n (kg C per kg of feedstock), determined according to 98.74(c).

MW = Molecular weight of the gaseous feedstock (kg/kg-mole).

MVC = Molar volume conversion factor (849.5 scf per kg-mole at standard conditions).

44/12 = Ratio of molecular weights, CO₂ to carbon.

0.001 = Conversion factor from kg to metric tons.

k = Processing unit.

n = Number of month.

GHGRP also has data on the carbon content of gaseous fuels used in the calculations. Given the relationship shown in Equation 1, for 2017, the assumed molecular weight of the feedstock can be derived so feedstock use aligns with reported emissions. Next, average carbon content and molecular weights (averaged over 2017-2021) can be used to derive feedstock use for 2010-2016 based on reported CO_2 emissions. Table 1 shows these calculations, with aggregated reported data from GHGRP in black⁴, calculated values in red, and averages of 2017-2021 data in blue.

Table 1: Calculation of Feedstock Based on Emissions Data, 2010-2021

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NG Feedstock Used (scf)	2.27E+11	2.33E+11	2.39E+11	2.42E+11	2.45E+11	2.43E+11	2.63E+11	3.29E+11	3.59E+11	3.69E+11	3.6E+11	3.34E+11
C Content (kgC/kg)	0.726	0.726	0.726	0.726	0.726	0.726	0.726	0.728	0.723	0.727	0.726	0.727
Molecular Weight (kg/kg-mole) - calc	17.32	17.32	17.32	17.32	17.32	17.32	17.32	17.23	17.23	16.70	17.76	17.68
Molar Volume Conversion (scf/kg-mole)	849.5	849.5	849.5	849.5	849.5	849.5	849.5	849.5	849.5	849.5	849.5	849.5
Total Process CO2 (MMT CO2)	13.57	14.01	14.23	14.44	14.64	14.42	15.61	19.10	20.52	20.76	21.44	19.91
Pet Coke Process CO2 (MMT CO2)	1.25	1.35	1.27	1.31	1.33	1.23	1.36	1.29	1.21	1.43	1.40	1.38
NG Process CO2 (MMT CO2)	12.32	12.66	12.95	13.13	13.31	13.19	14.25	17.81	19.31	19.33	20.04	18.53

The GHGRP data are generally equivalent or slightly higher than the feedstock energy use currently calculated in the Inventory.

3.3 Natural Gas Fuel Use

The Inventory currently does not track fuel use or emissions from ammonia production separately from total industrial sector energy use and emissions as reported under the Energy sector in the Inventory. The IPCC approach for estimating emissions from ammonia production indicates that both feedstock and fuel use emissions from ammonia production should be reported under the IPPU sector under CRF Category 2B1, rather than reporting feedstock related emissions in IPPU and other fuel use related emissions under the Energy sector.

⁴ The data reported from GHGRP is aggregated across all reporters and represents the totals across all ammonia produced from natural gas. The carbon contents and molecular weights therefore represent the averages across the whole industry.

Some data sources exist for fuel natural gas used in the ammonia production process over time including:

- EIA Manufacturing Energy Consumption Survey (MECS) data for fuel use of natural gas in ammonia production. Data are only available for some years as the survey is done every 4 years.
- Data derived from the GHGRP subpart C combustion emissions from natural gas used in ammonia facilities. Data on natural gas combustion emissions from facilities that report under subpart G are converted to energy based on the GHGRP default emission factors for natural gas combustion. Data on subpart C combustion emissions are available starting in 2011.

Figure 3 shows the results from the different sources compared to ammonia production data:

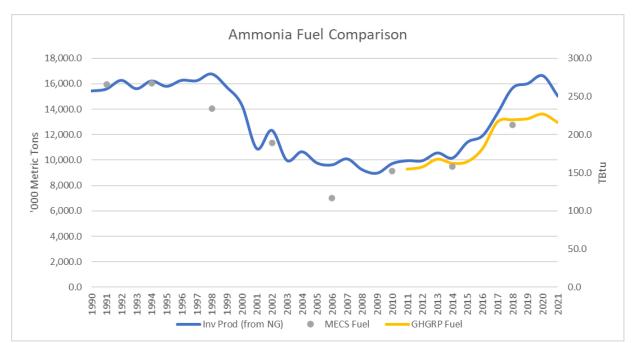


Figure 3: Comparison of Natural Gas Ammonia Fuel Use Values

The EIA data are limited in coverage and tracks the production quantities in some years while for other years seems to have a different trend. The data are reported for NAICS code 325311 Nitrogenous Fertilizers.

The GHGRP data derived from emissions aligns fairly well the MECS data and with ammonia production data for the years available; however, there is a larger difference in recent years which could potentially indicate newer production increases from more fuel-efficient facilities.

4 Analysis of Available Data

The proposed updated approach is to use the GHGRP data on CO₂ process emissions directly for the years it is available⁵. The approach would also utilize the GHGRP reported natural gas feedstock use for available years and derived feedstock use for earlier years. Natural gas fuel use from GHGRP data would also be used. Feedstock and fuel use ratios compared to current natural gas ammonia production would also be determined. Those ratios would then be applied to the current ammonia production data for prior years. This approach is used to account for the fact that the GHGRP production data does not line up exactly with the current production data in the Inventory and the current production data are better felt to represent industry production.

4.1 Natural Gas Feedstock Approach

The proposed approach is to take the CO₂ emissions from subpart G to represent emissions from ammonia production for the years 2010 on. The feedstock associated with those emissions are also taken from GHGRP reporting for years 2017 on and based on the derived results for 2010-2016 as shown in Table 1. To determine feedstock use and emissions for years prior to 2010, a ratio of feedstock natural gas used for the years 2010-2014, as back calculated from the GHGRP reported CO₂ emissions from natural gas ammonia production, over the natural gas ammonia production as determined by the Inventory. The years 2010-2014 are used since it covers the first 5 years of available data and was deemed to better represent historic ammonia production. In terms of reporting under GHGRP, 22 facilities reported from 2010-2012; 23 from 2013-2015; 26 in 2016; 28 in 2017 and 29 from 2018-2021, therefore, earlier years exclude the newer facilities that might not represent historic information. The average ratio for 2010-2014 is applied to the ammonia production data currently used in the Inventory over the time series 1990-2010. GHG emissions from that feedstock use is then determined based on heat content and emissions factors for natural gas used in the Inventory.

Table 2 below shows the data to be used and the annual and averaged 2010-2014 calculated ratio:

	Units	2010	2011	2012	2013	2014
Feedstock NG (deriveed from CO ₂)	Scf	2.27E+11	2.33E+11	2.39E+11	2.42E+11	2.45E+11
Ammonia Production (from NG)	'000 MT	9,727.3	9,952.0	9,951.2	10,565.3	10,162.1
Ratio Feedstock/Production	Scf/MT	2.33E+04	2.34E+04	2.40E+04	2.29E+04	2.41E+04
Average Ratio						2.36E+04

Table 2: Calculated Feedstock Ratio, 2010-2014

Applying that average ratio to the natural gas ammonia production data from the Inventory results in the feedstock natural gas use shown in Figure 4. This figure compares the calculated feedstock natural gas use values to overall production and current feedstock use values.

⁵ Emissions would be for ammonia produced from natural gas only and would still be adjusted to remove CO₂ used in urea production.

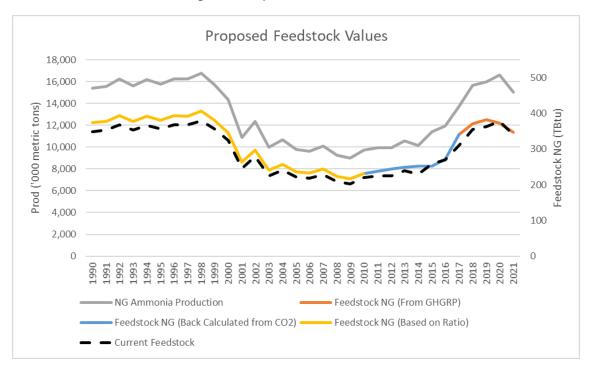


Figure 4: Proposed Feedstock Values

Results from the proposed approach show slightly more feedstock natural gas use compared to the current calculated amount. The proposed approach is determined to be more appropriate since the current method relies on a feedstock-based emission factor based on European facilities and the proposed method relies on reported data from U.S. facilities and facilitates accounting for both fuel and feedstock related emissions under IPPU (instead of reporting emissions under IPPU and the energy sector), which is consistent with 2006 IPCC Guidelines and UNFCCC reporting requirements.

4.2 Natural Gas Fuel Approach

As mentioned, currently the Inventory does not separately track fuel energy use for ammonia production. To be more consistent with *2006 IPCC Guidelines*, EPA is proposing to include natural gas fuel use as part of ammonia production emissions under the IPPU sector. Note: the fuel energy use and emissions will then be removed from current reporting under Energy to avoid double counting.

The proposed approach is to use a similar method as proposed for feedstock energy: calculate a ratio of the fuel natural gas use based on GHGRP data over the Inventory natural gas ammonia production data. The fuel natural gas use is derived based on Subpart C natural gas combustion emissions and the default emission factors for natural gas⁶. The ratio is determined for 2011-2015 as that represents the first 5 years of data and is considered to better represent historic fuel use since, as discussed above, it excludes newer facilities. The average ratio is applied across the 1990-2010 time series to the current Inventory reported natural gas ammonia production. Calculated values based on GHGRP data are used for 2011 to current. Table 3 below shows the GHGRP data used and the calculated ratio:

⁶ The back calculation was done based on CH₄ & N₂O emissions and default emission factors for each. The results were averaged to get the back calculated natural gas energy use estimates.

	Units	2011	2012	2013	2014	2015
Fuel NG (derived)	TBtu	154.5	157.3	167.6	162.2	164.3
Ammonia Production (from NG)	'000 MT	9,952.0	9,951.2	10,565.3	10,162.1	11,415.7
Ratio Fuel/Production	TBtu/'000 MT	0.0155	0.0158	0.0159	0.0160	0.0144
Average Ratio						0.0155

Table 3: Calculated Fuel Ratio, 2011-2015

Applying that average ratio to the natural gas ammonia production data from the Inventory results in the fuel natural gas use shown in the Figure 5 compared to overall production.

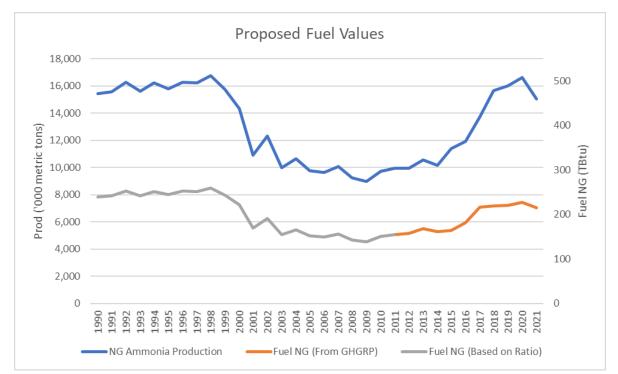


Figure 5: Proposed Fuel Values

5 Time Series Considerations

As noted above, the GHGRP data used in the proposed updates are only available for more recent years. The GHGRP data on CO_2 emissions from ammonia production are available starting in 2010, the natural gas used for ammonia feedstock is available starting in 2017 and the fuel combustion emissions from subpart C are available starting in 2011. Data on feedstock and fuel use have been back calculated for prior years based on the first 5 years of available GHGRP data.

6 Emissions Estimates for Ammonia Production in the 2023 GHGI

The proposed updates would result in a minor increase in natural gas ammonia production process emissions across most years. As mentioned, the emissions from petroleum coke ammonia production and the reductions in CO_2 associated with urea production would not be changed. The proposed

updates would also include natural gas process fuel emissions as part of the results reported for ammonia production under the IPPU sector. Figure 6 shows the results for current and proposed production and fuel use emissions, taking into account subtractions from urea production:

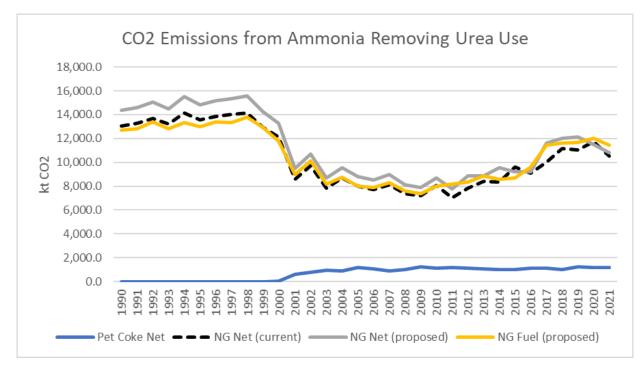
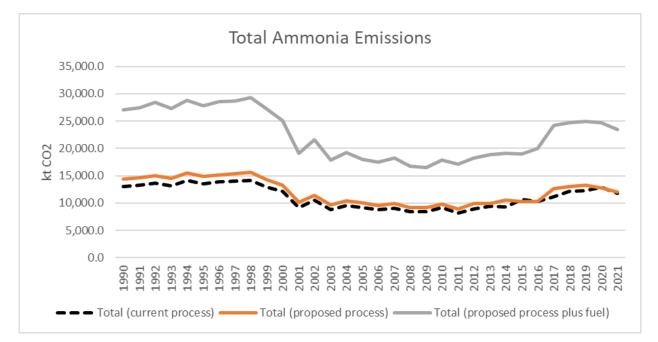


Figure 6: Comparison of Current and Proposed Emissions

Figure 7 shows the total results with and without the fuel use emissions included:

Figure 7: Current and Proposed Total Emissions



The following Table 4 shows the results for 1990,2005 and recent years indicating the changes from the current and proposed approach.

Source	1990	2005	2017	2018	2019	2020	2021
Current Process Total (net)	13.0	9.2	11.1	12.2	12.3	12.9	11.7
Proposed Total	27.0	18.0	24.2	24.7	25.0	24.7	23.4
Proposed Process (net)	14.3	10.0	12.7	13.0	13.3	12.7	12.0
Proposed Fuel	12.7	8.0	11.5	11.6	11.7	12.0	11.4
% Change in Process	10.0%	8.9%	14.3%	7.2%	8.6%	-1.5%	2.5%
% Change in Total	107.2%	96.4%	117.5%	102.7%	103.7%	91.5%	99.9%

Table 4: CO₂ Emissions from Ammonia Production (MMT CO₂ Eq.)

The proposed updates would have an annual average increase in process emissions of 8.3% over the 1990-2021 time series and an annual average increase of 102.5% including fuel use emissions. EPA would adjust emission reported under energy sector and allocate all emissions from ammonia production to the IPPU sector.

7 Request for Feedback

EPA is seeking feedback on the proposed updates to emissions from ammonia production in the Inventory. In particular, EPA would like feedback on the following questions:

- 1. Please provide recommendations for any information that could be added to the discussion to provide additional transparency and clarity.
- 2. Is there more information on the industry in terms of types of plants used over time and impact that might have on fuel and feedstock used?
- 3. The proposed approach for natural gas feedstock use is based on the use of derived data from GHGRP reported CO₂ process emissions and directly reported feedstock values from Subpart G. Is it reasonable to use this mix of data? Are the derived feedstock values based on the reported CO₂ emissions reasonable?
- 4. The proposed approach determines ratios based on GHGRP data for fuel and feedstock use and production data based on the current Inventory approach. Are there other approaches that could be used? Are there any benefits to alternate approaches?
- 5. The proposed approach uses 2010-2014 data on feedstock use and 2011-2015 data on fuel use to back-cast emissions. Alternatively, is there a different time period that would be more representative?
- 6. The Inventory currently uses a mix of sources for ammonia production information (e.g., ACC, Census, etc.). Is other data for ammonia production available? Are you aware of other data sources that could be used?
- 7. Ammonia fuel use is based on combustion data from facilities that report under subpart G of GHGRP. Those facilities are not specific to ammonia production, and fuel use and combustion emissions include other operations. Is it reasonable to include fuel use data for ammonia production based on this data since it is not specific to ammonia production?

- 8. Given lack of specific ammonia only production fuel use and given other industrial sectors mostly report fuel use under the energy chapter, should we just keep current approach of separating feedstock and fuel use data for ammonia in the Inventory even if this does not specifically match IPCC guidelines?
- 9. GHGRP reporting is based on facilities that emit GHG emissions; the brine electrolysis ammonia process does not emit CO₂ emissions. Therefore, ammonia production data reported under GHGRP might be lower than overall ammonia production. Are there other production processes used to produce ammonia that do not produce process-based CO₂ emissions, which might explain the differences in ammonia production data starting in 2018 (see Figure 1)?
- 10. Other non-standard operations such as startups, shutdowns, or malfunctions, may cause facilities to not produce as much ammonia but still have CO₂ emissions. Is there information available on the occurrence of these instances?
- 11. EPA is not proposing any changes to the existing methodology for ammonia production from petroleum coke or the reduction in CO₂ associated with urea production. Are there areas where those calculations could be updated as well? Are there other sources of information on those components that could be considered?

In addition to the questions above, see also pg. 2 of the IPPU Expert Review Process Guidance Memo and also please feel free to provide other feedback or questions on the approach.

Carbon Dioxide Transport, Injection, And Geologic Storage in The Inventory of U.S. Greenhouse Gas Emissions And Sinks

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.¹ This includes the use of data collected under EPA's Greenhouse Gas Reporting Program (GHGRP) on geologic sequestration of carbon dioxide (CO₂) and information on CO₂ transport and injection emissions.

1 Background and Current Inventory Methodology

Storage of captured CO_2 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_2 to extract additional oil and gas from underground reservoirs. Carbon capture and sequestration (CCS) refers to the capture and compression of CO_2 from power and industrial processes, transport of the captured CO_2 (typically in pipelines), and geologic sequestration.

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

- CO₂ 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: <u>Chapter 4</u>).
- CO₂ used in EOR operations is assumed to be sequestered permanently, with the exception of CO₂ 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 CO₂ 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 CO₂ include any CO₂ 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 CO₂ from EOR and other CO₂ occurring in the produced natural gas.
- For industrial processes that capture CO₂ it is generally the case that the captured CO₂ 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 CO₂ is accounted elsewhere in the Inventory it is netted out of the process. For example, the concentrated CO₂ 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 CO₂ is attributed to the urea consumption or urea application source category in the Agriculture sector

¹ 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 CO₂.

(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).

- CO₂ 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"). CO₂ 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 CO₂ as an emission from processing plants (Inventory section 3.6). If the CO₂ 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.
- CO₂ 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 CO₂ 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.² 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 CO₂ 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 CO₂.
- The IPCC does not provide a default method or emission factors for CO₂ 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 CO₂, and instead recommends that countries develop Tier 3 monitoring approaches to track any potential post-injection release of CO₂ 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.

² 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 5: Carbon Dioxide Transport, Injection and Geological Storage. <u>https://www.ipcc-</u> 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 CO₂ 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 CO₂ injected for storage, and potential associated CO₂ emissions associated with storage operations, corresponding to the storage site.
- Furthermore, under IPCC guidance, if CO₂ is captured in one country and exported for storage in a different country then the exporting country should report the amount of CO₂ captured, any emissions from transport and/or temporary storage that takes place in their borders and the amount of CO₂ exported. The exporting country would not count the CO₂ 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 CO₂ source category of the GHGRP (40 CFR Part 98, Subpart PP, also referred to as "Subpart PP"), EPA receives data from facilities with CO₂ production wells (natural CO₂ domes³) and other industrial facilities that extract or capture CO₂ streams. Importers and exporters of bulk CO₂ are required to report if total combined imports/exports of CO₂ and other GHGs exceed 25,000 tons CO₂e per year. Reporters provide information on the mass of CO₂ captured or extracted, data used to calculate that amount, and information on the amount of CO₂ 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.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CO ₂ Produced (Natural	48.7	49.9	50.3	49.8	50.9	45.7	38.7	40.7	38.7	39.0	27.2
Domes)											
Transferred to Food and	1.9	1.5	1.4	1.5	1.6	1.6	1.5	1.2	1.2	1.4	1.7
Beverage											
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 ^b	2.0	0.1	0.0	1.4	3.1	2.3	0.8	1.4	1.2	0.1	0.2
CO ₂ Captured (Industrial	16.1	16.3	16.0	18.6	20.5	19.1	17.3	19.3	19.8	22.4	17.5
Sources)											
Transferred to Food and	2.5	2.6	2.6	2.7	2.9	3.4	3.3	3.5	3.0	3.5	3.3
Beverage											
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 ^b	3.6	3.9	4.1	3.7	4.5	3.6	3.9	4.3	4.7	4.2	4.3

Table 1. Data from	GHGRP Subpart	PP for 2010-2020	(million metric tons CO ₂) ^a

³ The IPCC does not make specific mention of CO₂ produced from natural domes; however, it could be considered that CO₂ produced from naturally-occurring reservoirs is an anthropogenic activity (i.e., it would not have been emitted otherwise).

^a As of August 7, 2021.

^b 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 CO₂ 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 CO₂ 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 CO₂ received, data used to calculate the amount, and the source of the received CO₂ (if known); various mass balance equation inputs (mass of CO₂ injected, recycled, emitted, produced, equipment leaks, surface leakage, and entrained CO₂ in produced hydrocarbons), the amount of CO₂ 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.

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

Table 2. Data from GHGRP Subpart RR for 2016-2020 (metric tons CO₂)^a

^a As of August 7, 2021.

Facility	CO ₂ sequestered	CO ₂ equipment leaks	CO ₂ surface leaks
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
Total:	6,764,879.0	51,029.0	22,974.7

Table 3. Data from GHGRP Subpart RR for 2020 by Facility (metric tons CO₂)^a

^a 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 CO₂ underground for EOR, or for any purpose other than geologic sequestration, report data on CO₂ received for injection under the Injection of CO₂ 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 Report⁴ and the U.S. Department of Energy National Energy Technology Laboratory Carbon Capture and Storage Database⁵, include information on CO₂ captured from industrial sources for CO₂-EOR or other storage.
- Many corporate annual reports and 10-Ks provide information on CO₂ captured for CO₂-EOR and/or storage. Also, considerable information is provided on company websites.
- Facilities supported by government R&D funding that are capturing CO₂ 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 CO₂ Emissions from Capture

In general, for sources where CO₂ 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 CO₂ Emissions from Pipeline Transport

EPA could use IPCC default Tier 1 emission factors to estimate CO_2 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 CO₂ transport associated with receiving Subpart RR facilities. The length of CO₂ 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 CO₂ pipeline network in the United States. This could be done through a methodology such as: (1) Gather information on the lengths of CO₂ 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_2 capture sources. If emissions are accounted at the source for all capture except for sequestration,

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

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

the first approach might be the most appropriate so as to avoid double counting of emissions. If emissions for all captured CO_2 are netted out or not completely accounted for at the source, then the second option might be more relevant.

4.3 CO₂ Emissions from Injection

As noted above, the IPCC Guidelines do not provide a default method for estimating emissions from CO₂ injection. GHGRP reporters provide an estimate of fugitive emissions from CO₂ injection systems (assumed to be under CO₂ equipment leaks) under Subpart RR. This information could be used to estimate national emissions associated with CO₂ 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 CO₂ emission between the capture facility fenceline 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 CO₂ Sequestration

GHGRP reporters under Subpart RR provide an estimate of storage and any leakage of CO_2 from storage (assumed to be under CO_2 surface leaks in the tables above), which could be incorporated into the Inventory.

However, while reporting of emissions associated with CO_2 sequestration sites (i.e., leakage) is fairly straightforward, there are challenges in accurately accounting for CO_2 sequestration in the Inventory. The IPCC approach calls for subtracting the amount of CO_2 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_2 that is reported under Subpart RR and could make the following updates to the Inventory accordingly:

- If the CO₂ 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 CO₂ 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 CO₂ was from any other industrial process source we could adjust the Inventory to subtract that CO₂ capture from the source in question. This would include CO₂ 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 CO₂ is from natural domes or Industrial sources. CO₂ capture/supply can come from both industrial sources (e.g. natural gas processing plants) and natural CO₂ domes. Because CO₂ pipelines often transport CO₂ from a mix of sources, it can be difficult to determine the source category of captured CO₂ (e.g., for 2020 Subpart RR reporters, Denver Unit and Hobbs field are in the Permian Basin which has several CO₂ sources connected to the system including natural CO₂ domes and industrial CO₂ sources). Due to the interconnected nature of CO₂ 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 CO₂ 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 CO₂ 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_2 as the source of CO_2 sequestered. This biogenic CO_2 , absent capture, would not be included in the Inventory as an energy related emissions source.⁶ Where this CO_2 is captured by the ethanol plant before it can be released to the atmosphere, it is a CO_2 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_2 captured may be from biomass fermentation and not necessarily a combustion source, however, the CO_2 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 CO₂ is not able to be tracked through the GHGRP (see above). In this instance, EPA is considering approaches for estimating the source of the CO₂. The approach would need to distinguish between natural dome CO₂ sources and specific industrial CO₂ sources, and where applicable, make it clear that the quantity of CO₂ 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 CO₂ 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 ₂ Sources (metric
tons CO ₂) ^a

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

^a As of August 7, 2021. Note: Totals may not sum due to rounding.

^b MMT = million metric tons

EPA could use the amount of CO_2 captured/supplied from industrial versus natural domes and assume that CO_2 stored in subpart RR has the same sources (i.e., assume that in 2020 ~39% of the sequestered CO_2 comes from an industrial source and ~61% comes from natural CO_2 domes).

⁶ 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_2 sequestration in the Inventory. Two options are discussed below but EPA is also requesting recommendations for other options not listed.

Option 1: Assign CO₂ Storage for Each Storage Site to the Major Source of CO₂ Emissions Capture

Assumptions could be made about the major source of CO₂ 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 CO₂ sequestered in 2020 came from industrial sources. According to the Global CCS Institute Global Status Report, the largest sources of CO₂ 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).⁷ Therefore, it can be determined that since natural gas processing is the major source of CO₂ in the Permian Basin, the 39% industrial source CO₂ removals from that site belong in the natural gas processing source in Inventory reporting. The remaining 61% would be assumed to come from CO₂ domes.

As another example, for the Archer Daniels Midland facility it could be assumed that 100% of the CO₂ 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 CO₂, 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 CO₂ from all industries for which carbon capture projects are operational that may feed into a sequestration site. The total amount of industrial source CO₂ captured for geologic storage in the United States would be equally (or by some factor) subtracted from industry/sectors which provide CO₂ 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 CO₂ domes.

While this approach subtracts emissions from a larger industry base representing the entire US, reflecting a potentially more accurate representation of CO_2 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-

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

over-year. In addition, subtracting CO₂ 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 CO₂ underground for EOR, or for any purpose other than geologic sequestration, report data on CO₂ 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 CO₂ 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 CO₂ injected, among other data.⁸

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 CO₂. The 2006 IPCC Guidelines indicates that geological CO₂ storage may take place either at sites where the sole purpose is CO₂ storage, or in tandem with EOR. However, they also indicate that some of the emission pathways from EOR operations differ from those for geological CO₂ 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_2 from natural gas processing and from natural domes.

Subpart UU only accounts for the amount of new CO₂ received for injection and does not opine on the fate of that CO₂. Note that treating all EOR CO₂ as a release to the atmosphere in the Inventory would overestimate actual CO₂ emissions given that the process of EOR can lead to incidental storage of most CO₂ that is received for injection. In an EOR project, a portion of the injected CO₂ gets trapped in the reservoir in the form of one or more CO₂ trapping mechanisms (stratigraphic trapping, dissolution in residual oil/brine, residual trapping due to hysteresis, and mineral trapping). The remaining portion of the CO₂ 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 CO₂. Volumes of CO₂ that are recycled at the last stage of the EOR project. Over the life of an EOR project, the amount of newly received CO₂ decreases as the quantity of CO₂ produced from the reservoir through recycling increases. The geology of an oil and gas reservoir can effectively trap CO₂ underground for thousands of years.

⁸ We note that CSA/ANSI ISO 27916:2019, "Carbon Dioxide Capture, Transportation and Geological Storage— Carbon Dioxide Storage Using Enhanced Oil Recovery (CO₂-EOR)", establishes a protocol for documenting the containment of CO₂ injected in an EOR operation and quantifying the amount of CO₂ 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 CO₂.

5 QUESTIONS FOR STAKEHOLDERS

5.1 Data Sources

The GHGRP has data reported starting in 2010 on CO₂ 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 CO₂ supply? Is that data consistent with GHGRP data? If so, how should it be combined?

5.2 Methodology

- EPA has identified potential options for incorporating CO₂ 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 CO₂ Transport, Injection, and Geologic Storage and available data from the EPA GHGRP? Should EPA consider alternative methods, particularly for assigning CO₂ emission reductions as a result of geologic sequestration to an emitting source category?
- 2. Would developing this percent split between CO₂ dome and industrial CO₂ 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 CO₂ capture be counted, in particular for industrial sources? (For example, for ethanol fermentation CO₂, 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 CO₂.
- 6. Are there are resources or data that EPA should consider related to captured CO₂ 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?