Summary of Expert Review Comments and Responses:
Draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019*

July 2021
U.S. Environmental Protection Agency
Office of Atmospheric Programs
Washington, D.C.

Responses to Comments Received during the Expert Review Period on the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019*

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 sectoral chapters (e.g. Energy, IPPU, Agriculture, etc.) of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019* for a preliminary Expert Review of estimates and methodological updates prior to release for Public Review. The Expert Review ranged from 30 days by sector and included charge questions to focus review on methodological refinements and other areas identified by EPA as needing a more in-depth review by experts. The goal of the Expert Review is to provide an objective review of the Inventory to ensure that the final Inventory estimates, and document reflect sound technical information and analysis. Conducting a basic expert peer review of all categories before completing the inventory in order to identify potential problems and make corrections where possible is also consistent with IPCC good practice as outlined in Volume 1, Chapter 6 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

EPA received 62 unique comments on as part of the Expert Review process. The verbatim text of each comment extracted from the original comment letters is included in this document, arranged by sectoral chapters. EPA's responses to comments are provided immediately following each comment excerpt. The list of reviewers, dates of review and all charge questions distributed to reviewers are included in the Annex to this document.

Chapter 3. Energy

Comment 1: General feedback on inventory estimates
The chapter sections reviewed were generally clear and intelligible. The limitations of the report arise primarily from shortcomings in the underlying data sets, which were generally not developed to support greenhouse emissions estimates (e.g. EIA data on fuel sales, FAA flight data). The report works around these circumstances and provides a clear explanation of how final estimates were arrived at. However, the entire national endeavor (including state and local inventory activities as well as policy development) would benefit from a coordinated approach across agencies that specifically targets inventory questions.

Response: EPA coordinates with EIA and FAA on use of existing data and will discuss future data needs as appropriate when considering any future state-level disaggregation. EPA would be interested in further clarifications of any shortcomings in underlying data sets and specific impacts on GHG estimates.

Chapter 4. IPPU

Comment 2: Overall impressions of IPPU chapter
Overall, the document is transparent with the addition of low voltage PFC emissions as another PFC emissions occurring in the aluminum production process. However, the low voltage anode effect (LVAE) is not an adequate definition because PFCs can be generated in the absence of an anode effect. Therefore, a better terminology will be to use "low voltage PFC emissions". See "PFC & Anode Products, Myths, Minimization and IPCC Method Updates to Quantify the Environmental Impact", David Wong and Barry Welch, Light Research Metals Centre.

Response: EPA appreciates the reference and will review the cited paper as part of planned improvements. The terminology used in the Inventory to describe these emissions is consistent with terminology in the 2019 Refinement to the 2006 IPCC Guidelines.

Comment 3: Response to question about methodology used for calculation of Low Voltage Anode Effect (LVAE) emissions
Question: Do you agree with the methodology of using the legacy PFPB (PFPB-L) emission factor for the calculation of LVAE emissions in place of CWPB for U.S. smelters?

Yes, the PFPB Legacy smelters has lower line currents of less than 350 KA and are from older cell design mostly operated since 1960s with less than 24 anodes. The proposed Tier 1 factor is an initial estimate based subject to improved estimates when Tier 3 slope factors are more available. See the technology description in the 2019 IPCC refinement section 4.4.1" Introduction to Primary Aluminium". EPA should generate a similar TO-15 method procedure that the aluminum industry should adopt.

Response: EPA appreciates the feedback and will review the cited section as part of planned improvements.

Comment 4: Response to question about modern PFPB (PFPB-M) facilities

Question: Do you concur that there are no modern PFPB (PFPB-M) facilities in the United States?

Yes, modern PFPB include new cell technologies AP30, and later APX, EGA DX ad DX+ or later with line currents greater tan 350 KA with 24 or more anodes. Alcoa US smelters are of lower amperages.

Response: EPA appreciates the feedback on the occurrence of modern PFPB facilities for Alcoa's US facilities.

Comment 5: Response to question about accuracy and current state of industries described in IPPU Chapter 4.19 Aluminum Production (CRF Source Category 2C3) page 4-52 to 4-58.

Yes, the state of the Aluminum industry is current and well described. The inclusion of low voltage PFC emissions using Tier 1 production-based methodology (IPCC 2019) is adequate for national reporting purposes at this time since new measurement procedures and technologies are being proposed in the aluminum industry to be carried out in 2021-2022. One important note is that the updated Tier 1 emission factor are obtained from 46 PFPB measurements that included LV PFC emissions (J. Marks and P. Nunez, "Updated Factors for Calculating PFC Emissions from Primary Aluminum Production", Light Metals 2018, pp 1519-1525), which are from the modern PFPB technologies, therefore not from Legacy PFPB technologies, which are most of US smelters. The Tier 1 specifies that low voltage PFC emissions are approximately 13 % of total emissions, and this is an approximation with high uncertainty. The Tier 1 uncertainties are shown in Table 4.15 of IPCC 2019 refinement. Tier 3 or actual measurements of low voltage PFC emissions should be more accurate. There is no certified method to measure LV PFC emissions. The International Aluminum Institute (IAI) is publishing in December a Good Practice Guidance to measure PFC emissions to update the 2008 USEPA/IAI PFC Measurement Protocol. It includes the latest information on the main methods for measuring LV, HV (including cell start-up, CSU) PFC emissions as outlined in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Alcoa was part of the review with inclusion of latest technologies, practices and procedures through research paper published at TMS since 2015.

The industry is focusing also on strategies to manage, measure and account for low voltage PFC emissions. Alcoa, Hydro, Rio Tinto and Alouette will test new sampling techniques and methodologies to report PFC inventories and reduce PFC emissions through an IAI proposal to be carried out in 2021-2022. EPA should review the methodology of how to distinguish and measure low voltage and high voltage PFC emissions using a combination of gas bags and canisters sampling with FTIR and GC-MS analytical techniques. In addition, if there is no need to distinguish low voltage and high voltage PFC emissions, using integrating canisters sampling with GC-MS analyses is the most sensitive technique and should be recommended as an EPA TO-XX method to measure total PFC emissions. Similar EPA methods exist for VOC, like TO-15, however time measurement frequency should be evaluated. Alcoa experience recommends measurement time being between 6-14 days, or even do measurements multiple times within a year to average total PFC emissions to calculate the uncertainty per plant. Low voltage PFC emissions are highly variable on process stability based on pot room cycle during anode changes, tapping, pot starts, etc. Therefore, a minimum of 3 pot cycles (48 hours per cycle) is needed to average the low voltage PFC emissions contribution. The aluminum industry will also test a continuous monitor, which might be better used to reduce PFC emissions by optimizing pot control processes.

Response: EPA used the Tier 1 factor for PFPB-Legacy ($PFPB_L$), available in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, to estimate LVAE emissions. Unlike the paper cited in the expert review comments, the $PFPB_L$ in Table 4.15 of the 2019 Refinement does not

include data from $PFPB_M$. Table 4.15 of the 2019 Refinement notes in footnote a that "PFPBL emission factors and uncertainties reported in (Marks & Nunez 2018b) erroneously included data from another technology class (PFPBM). This has since been corrected in the emission factor and uncertainty values reported here (expert opinion – Dr Jerry Marks)". EPA appreciates the expert review comments acknowledging that the industry is appropriately described and takes note of the ongoing work to advance methods to more accurately monitor low voltage PFC emissions.

Comment 6: Broken link on page 4-54
On page 4-54 the reference link 31 "www.epa.gov/ghgreporting/documents/pdf/infosheets/aluminumproduction.pdf" doesn't work. The link should be corrected to www.epa.gov/ghgreporting/subpart-f-aluminum-production

Response: EPA appreciates comment noting the broken link. See updated link on page 4-94 of the final report.

Chapter 5. Agriculture

Comment 7: Include reference to aquaculture discussion in LULUCF chapter
The chapter sections reviewed were generally clear and intelligible.

The chapter does not discuss aquaculture, but some information on N2O emissions from aquaculture in coastal wetlands is presented in Chapter 6, Land Use, Land-use Change, and Forestry. It would be useful to include a reference to that discussion in the introduction to Chapter 5. It is beyond my area of expertise to know if the discussion in Chapter 6 is complete or if additional research would be of benefit.

Response: ***EPA appreciates the feedback. We have included a reference to aquaculture in the introductory section of Chapter 5. There are many aspects of Chapter 5 that relate to Chapter 6, and vice versa, and it is not possible to provide reference to all of them*.**

Comment 8: American bison population
Page 5-3, lines 23 - 24. The text indicates that the population of American bison more than tripled from 1990 to 2019, but Tables 5-3 and 5-4 show that emissions were essentially unchanged. Some explanation would be useful.

Response: EPA appreciates the feedback. There was an error with Tables 5-3 and 5-4 in the expert review draft but has been updated with publication of the final 1990-2019 Inventory report.

Comment 9: Wet vs. dry waste disposal systems
Pages 5-10, lines 12 - 44, and Tables 5-7 and 5-8. It would provide additional insight if data on wet and dry systems could be separated in the time series in Tables 5-7 and 5-8. Alternatively, data on wet vs. dry overall (combining livestock categories) presented as a time series could also demonstrate the relative influence of waste disposal types over time.

Response: EPA appreciates the feedback. We will consider additional disaggregation of emissions reporting as part of future improvements as data allow.

Comment 10: Point readers to formula for calculating direct N_2O emissions from manure management
Page 5-14, Lines 33 - 39. Since the verbal description of the formula is unwieldy, it would be useful to note to readers that the actual formula is presented in Annex 3.11. The earlier reference to Annex 3.11 (at Line 26) is at the end of a bullet point and simply says to see the annex. Adding a more specific instruction at lines 33 - 39 would be more to the point. This could be included as a footnote or in the text. Alternatively, the actual formula could be inserted.

Response: EPA appreciates the feedback. We have added additional references to specific sections of Annex 3.11 within the Manure Management Chapter 5.2. Moving forward, EPA will continue to consider how best to reflect the current methodologies referenced in the chapter and relevant annex text.

Comment 11: Accessibility of references
Page 5-19 ff. References. (Also applies to Annex references.) Accessibility to references can be improved,. To the extent practical, sources should be available online, and a URL to the documents should be included in the references section. This is especially important for sources that are not readily available through normal research channels, e.g. contractor reports. For example, ERG references do not turn up in web searches or through the EPA home page search bar, and there is no search function on the erg.com home page. Because the inventory report relies heavily on such sources, verifiability and understanding will benefit by providing greater access. If material is proprietary and cannot be made public, that needs to be made clear in the text.

Response: EPA appreciates the feedback. We will assess the feasibility to publish original references in a more accessible and usable format with forthcoming Inventory publications. Full citations for all references cited in the report can be found in Chapter 10 of the report for full transparency.

Chapter 6. LULUCF

Comment 12: Definition of litter
Page 6-2, Line 17. The expression "fumic layer" in the definition of litter does not appear in several dictionaries searched, and only turned up in a handful of search results on Google and Duck-Duck-Go (one of which was the previous inventory report). Readers may therefore not recognize this term. The definition of litter carbon on page 6-12, lines 39-40, is more to the point. Orienting readers by referencing soil horizons may also be helpful.

Response: EPA appreciates the feedback and has revised the definition of litter within the final Inventory report, on page 6-23, to align with the definition on page 6-33 to be more accessible to readers.

Comment 13: Values in parentheses
Page 6-6, Table 6-1. It would be helpful to note that values in parentheses refer to uptake.

Response: EPA appreciates the suggestion. Please refer to the "Notes" footnote below the Table 6-8 on page 6-28 of the final Inventory report which provides this clarification. EPA has not added additional notes at this time.

Comment 14: Distinguishing between lines in Fig. 6-2

Page 6-9, Figure 6-2. Because several lines lie on top of one another and have similar colors, it would be useful to distinguish them with line patterns, e.g. dots and dashes.

Response: EPA appreciates the suggestion. However, EPA has not made updates at this time to this figure (Figure 6-5 in the final report) because there are multiple carbon pools with estimates around zero, and adjustments to the figure as suggested by the commenter will not further distinguish the lines in the figure. EPA will consider the feedback for future improvements.

Comment 15: Finalizing reference to paper by Domke, et al. before report release
Page 6-11, Line 22. The reference to the unpublished paper by Domke, et al., needs to be finalized before the official report is released. Barring that, sufficient information must be provided so that the document can be found once it is finally released. This reference also needs to be added to the bibliography.

Response: EPA appreciates the feedback and refers commenter to Annex 3.13 of the final report which includes details and additional information related to the methods and data. Consistent with prior reports, Annex 3.13 also includes the full list of references cited starting on page A-442.

Comment 16: Reference to paper for Domke, et al.
Page 6-79, lines 31-32. Should the reference for Domke, et al., (2016) come after Domke, et al., (2013) (currently listed on the following page)?

Response: EPA appreciates the feedback and has implemented this change.

Chapter 7. Waste

Comment 17: Wastewater N_2O Emission Factor
The value of the emission factor used in the table on page 7-38 (also included below) is not consistent with the value obtained from the IPCC document, '2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories". The corresponding value in the IPCC document is 0.016 k N_2O-N/kg influent N (or 1.6% of the influent nitrogen load), which is one order of magnitude lower.

Variable	Variable Description	Units	Inventory Years: Source of Value
Emissions from Centrally Treated Aerobic Systems (Other than Constructed Wetlands)			
% $aerobic_{OTCW}$	Flow to aerobic systems, other than constructed wetlands only / total flow to POTWs[a]	%	1990, 1991: Set equal to 1992 1992, 1996, 2000, 2004: EPA 1992, 1996, 2000, 2004a, respectively Data for intervening years obtained by linear interpolation. 2005-2019: Forecasted from the rest of the time series
$EF_{aerobic}$	Emission factor – aerobic systems (0.16)	kg N_2O-N/kg N	1990-2019: IPCC 2019
44/28	Conversion factor	Molecular weight ratio of N_2O to N_2	Standard conversion
$1/10^6$	Conversion factor	kg to kt	Standard conversion

[a] Value of this activity data varies over the Inventory time series.

Furthermore, the value in the IPCC document for this emission factor (or strictly speaking, emission fraction) is an average calculated from different studies including the most extensive one to date conducted in the United States (Ahn et al. 2010). If we focus just on the plants in the United States, then the values for this emission fraction for mainstream centralized wastewater treatment systems including both biological nitrogen removal (BNR) and non-BNR processes are in the range 0.0048 ± 0.0059 kg N_2O-N/kg influent N (adapted from (Ahn et al. 2010)). Alternatively, if we follow the same approach as that of the IPCC (linear regression of emission against influent N loading), then the estimated emission fraction is 0.0075 kg N_2O-N/kg influent N with a R^2 value of 0.3552 and a p-value of 0.0015 (data used for regression presented in Table A on pages 2-3 of this document and also presented in Figure A on page 3 of this document). Notwithstanding that these values are averages or estimated using linear regression, these are still more reasonable (and lower) relative to the IPCC value, which is skewed towards the very high end of the range observed in the United States (as identified in the primary study (Ahn et al. 2010). It would be useful to include a comparison of the emissions calculated using the previous two-emission factor approach (for BNR and non-BNR systems and normalized to population equivalents) and this newly proposed approach.

Table A. Data used from (Ahn et al. 2010) to re-calculate an emission fraction for this review

Process	Influent N loading g N/d	N2O emission rate g N_2O-N/d[#]
Separate-stage BNR	1.80E+06	540
	2.30E+06	230
Four-stage Bardenpho	8.60E+05	1376
	7.40E+05	4440
Step-feed BNR 1	3.10E+06	49600
	2.90E+06	17980
Step-feed non-BNR	8.60E+06	15480
	8.90E+06	160200
Plug-flow 1	1.80E+06	7200
	1.80E+06	7380
Plug-flow 2	6.30E+05	3906
	6.60E+05	594
MLE 1	6.80E+05	476
MLE 2	6.90E+05	414
Step-feed BNR 2	2.20E+06	33000
Oxidation ditch	3.90E+05	117
Step-feed BNR 3	7.80E+06	3900

[#]: Calculated from (Ahn et al. 2010)

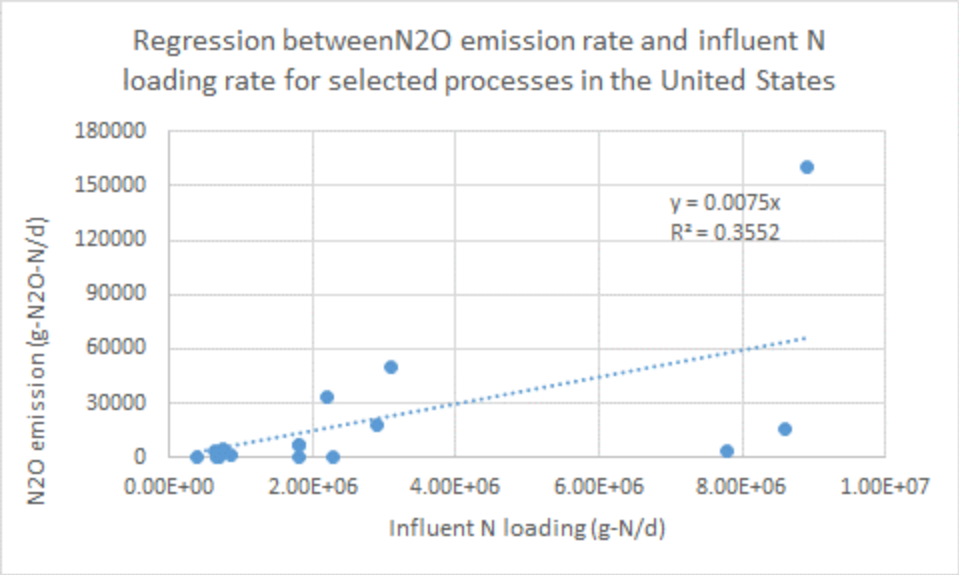

Figure A. Estimation of emission factor using linear regression of United States plant data (adapted from (Ahn et al. 2010)).

It might be useful to also consider a more mechanistic approach to estimate emissions based on the actual performance of the specific wastewater treatment process if it might not be possible to measure such emissions. N_2O emissions are a function of the concentrations of the different N-species (such as ammonia, nitrite and nitrate) as well as operating dissolved oxygen concentration in the wastewater treatment processes themselves (Tables II and III in (Ahn et al. 2010)). Where possible and feasible, if such operating data are available in conjunction with measured N_2O emissions values, plant-specific models could be developed the use of which could provide a more efficient option to estimate emissions.

I focus on the US plants and the US study primarily because the data were obtained using an EPA approved methodology. We don't know how reliable the estimated or measured emissions are from the other studies referenced in the 2019 IPCC study.

Ahn, J. H., S. Kim, H. Park, B. Rahm, K. Pagilla and K. Chandran (2010). "N_2O Emissions from Activated Sludge Processes, 2008-2009: Results of a National Monitoring Survey in the United States." Environmental Science & Technology **44**(12): 4505-4511.

Response: With regard to the error in emissions factor noted by the commenter, see page 7-43, EPA has fixed the error, which was a typo in the text (i.e., the correct value was used in the calculation of emissions). With regard to the comment on the increased accuracy of using a U.S.-specific emission factor instead of an IPCC default factor and further accuracy of using one emission factor for biological nitrogen removal systems and a second for systems other than those with biological nitrogen removal, EPA agrees. However, it is not clear if there are sufficient data to support this change. On page 7-52, we have included this in the Planned Improvements discussion for Chapter 7.3 Wastewater Treatment and Discharge in the Inventory report as follows so that we may explore for the next Inventory cycle: Review whether sufficient data exist to develop US-specific N_2O emission factors for domestic wastewater treatment systems, including whether emissions should be differentiated for systems that incorporate biological nutrient removal operations.

Comment 18: Aerobic/Anaerobic System Terminology

Terminology of aerobic-anaerobic systems is misleading and not representative. Essentially, this terminology ignores distinctions between Nitrification-only and Nitrification-Denitrification processes. Whereas the former are largely aerobic, the latter include both aerobic and anoxic processes. Perhaps an alternative term for aerobic processes could be considered, such as 'activated sludge and variants' or something more appropriate.

Response: EPA agrees that biological systems used for the treatment of wastewater may be comprised of aerobic, anaerobic, and/or anoxic zones. EPA generally adopts the terminology used by IPCC guidance documents, which has grouped these systems into one category referred to as "centralized aerobic wastewater treatment plants." EPA will consider future improvements to the terminology to clarify that "aerobic" systems may in fact include multiple zones.

Comment 19: Discussion on N_2O Emission Variability
It would be useful to include a discussion on the complexity and variability and factors leading to variability in N_2O emissions from biological wastewater treatment processes.

Response: EPA agrees and plans to incorporate such discussion following the review of data to potentially develop U.S.-specific N_2O factors.

Comment 20: Ranges for Emission Factors
Another consideration would be to present the range when mentioning or using a single emission factor.

Response: EPA believes the Uncertainty discussion within Chapter 7.2 frames the variability around the estimates.

Comment 21: Updated Research on N_2O Emissions from Wastewater
Page 7-17, Lines 34-40: Since the publication of the primary field-study (Ahn et al. 2010), more advances have been made in terms of the factors that lead to nitrification-related N_2O production and emissions (Chandran et al. 2011). It might be useful to point to these and illustrate that the configurations and conditions integral to BNR operations are quite similar to those that enable N_2O production during nitrification (and denitrification).

Ahn, J. H., S. Kim, H. Park, B. Rahm, K. Pagilla and K. Chandran (2010). "N2O Emissions from Activated Sludge Processes, 2008-2009: Results of a National Monitoring Survey in the United States." Environmental Science & Technology 44(12): 4505-4511.

Chandran, K., L. Y. Stein, M. G. Klotz and M. C. M. van Loosdrecht (2011). "Nitrous oxide production by lithotrophic ammonia-oxidizing bacteria and implications for engineered nitrogen-removal systems." Biochemical Society Transactions 39(6): 1832-1837.

Response: EPA appreciates and thanks the commenter for providing data sources for their comment and will review these sources as part of planned improvements.

Comment 22: Stripping of N_2O in aerated and non-aerated zones
Page 7-17, Lines 39-40: "No matter where N_2O is formed it is typically stripped to the air in 39 aerated parts of the treatment process." Stripping also occurs in non-aerated zones at rates lower than in aerated zones. This is a very minor comment.

Response: EPA appreciates the feedback. The text Chapter 7.2 has been edited to reflect changes based on this comment regarding stripping (see page 7-21).

Comment 23: Answering landfill-specific charge question
Question: Please comment and/or provide additional data on whether the findings from recent Food Waste Alliance surveys that approximately 84 percent to 94 percent of food waste from the manufacturing sector is repurposed versus being landfilled is representative of the food and beverage sector.

[I assume you mean "representative of the food and beverage manufacturing and processing sector" not of the entire food supply chain?]

The FWRA study is the best available data that we could find about how much wasted food the industrial sector (i.e., food and beverage manufacturers and processors) generates and how they manage it. In our 2018 Wasted Food Report (https://www.epa.gov/sites/production/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf), which builds off the Scoping Memo but provides EPA's 2018 wasted food estimates (that go into the 2018 Facts and Figures Report), we discuss the industrial sector and the break out of how it manages wasted food. See section 4.1.1 and then the very last page for the Table that shows the estimates of how much wasted food from the food and beverage manufacturers and processors went to each pathway. In that Table, you can see that EPA estimates that the food and beverage manufacturers and processors sent 1,334,720 tons of wasted food to landfill out of 39,821,247 tons generated, which is about 3.4% landfilled (for 2018). You can see the tonnage estimates for how much went to other management pathways.

Other sectors in the food system handle their wasted food differently from the manufacturers and processors, as you can see from the table. Specifically, other sectors (such as retail, restaurants, households, etc) landfill at a much higher rate, and send food to animal feed and land application at a much lower rate. The overall averages of all sectors are in Table 5.

The methodology is not clear on the amount of waste from the food and beverage sector that is specifically disposed in industrial waste landfills versus a combination of MSW and industrial waste landfills.

We did not research the question of how much food waste from the food and beverage manufacturers and processors goes to industrial vs. MSW landfills. The assumption has been that it mostly goes to industrial landfills and that's one of the reasons EPA doesn't include it in the Facts and Figures Report but we did not research this.

Response: EPA thanks the commenter for confirming our understanding of the amount going to landfills and that it does not specifically break out what is disposed in MSW versus industrial waste landfills. We will retain the current industrial waste landfills methodology for the 1990-2019 inventory and will look at food waste disposal in industrial waste landfills in more detail prior to the 1990-2020 inventory.

Comment 24: Answering landfill-specific charge question

Comment 25: MSW Management Pathways

Box 7.2- there are more ways than those listed in which MSW can be managed. For example, for food, in addition to landfill, combustion, composting and AD, there is also animal feed, sewer/wastewater (i.e., sending food waste down the drain), rendering of fats, oils, and grease, and land application. You may want to expand the list in the box or footnote it. We made changes to the wasted food methodology in the 2018 Facts & Figures Report that was published on 11/12/20, so that paragraph should be updated:

Current language: "MSW that is not recycled, composted, digested, or combusted is assumed to be landfilled. The data presented in the report are nationwide totals. The next Facts and Figures report will include estimates for food waste managed by anaerobic digesters."

Change to: "MSW that is not recycled or composted is assumed to be combusted or landfilled, except for wasted food, which uses a different methodology and includes nine different management pathways. The 2018 Facts and Figures Report (2020) uses a methodology that expanded the number of management pathways to include:

- animal feed;
- bio-based materials/biochemical processing (i.e., rendering);
- codigestion/anaerobic digestion;
- composting/aerobic processes;
- combustion;
- donation;
- land application;
- landfill; and
- sewer/wastewater treatment.

Response: EPA thanks the commenter for this input. We have made the requested, and additional, revisions to the text box (text box 7-3 on page 7-12) to add in excess food reuses and other management pathways.

Comment 26: EPA Facts and Figures Report
Figure 7-2, 7-3, 7-4: Please use the most recent Facts and Figures Report (2018). https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancingsustainable-materials-management

Response: This comment is referring to the figures and tables in Box 7-3. The 2018 Facts & Figures Report was published on November 12, 2020 and was not available prior to the preparation of the Expert Review draft on which these comments are based. We have since updated Box 7-3 with the most up to date Facts & Figures report data.

Comment 27: Miscellaneous Comments on Page 7-48
Line 1- what is your source for the composting totals?

Line 34: "donating excess waste for human consumption"-- I strongly recommend changing this to "donating excess food for human consumption" -- we are very careful to never say that we donate waste to feed humans.

Line 38-41: Strongly recommend using EPA's composting estimates published in 2018 Facts & Figures Report (https://www.epa.gov/facts-and-figures-about-materials-wasteand-recycling/advancing-

sustainable-materials-management - see the fact sheet and the data tables for the food (the commercial, residential and institutional sectors) and the yard waste estimates) and the 2018 Wasted Food Report (https://www.epa.gov/sites/production/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf)- here you can find the estimates for the food manufacturers and processors, as well as the commercial, residential and institutional sectors (Facts and Figures estimates do not include the food manufacturers and processors). These EPA sources are more current than the BioCycle ones.

Response: With regard to the comment on Line 1, the amount of material composted each year is sourced from various Facts and Figures reports (Table 35). Note that the EPA Facts & Figures data are presented in short tons, while the National Inventory and IPCC Guidance uses metric tons; the numbers will be slightly different due to the conversion factor. Because each Facts & Figures report only presents select data, we pull from multiple reports to compile data from 1990 to the latest Inventory year. The latest report was published in November 2020 and was not available for the 1990-2019 Expert Review draft of the Inventory. Data for the years 2017 and 2018 have been updated in the final Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019. All quantities of material composted are taken from Table 35 of the Facts & Figures reports. We extrapolate the amount composted based on population growth for years that are not yet available in the latest Facts & Figures report (e.g., 2019 in the 1990-2019 inventory). The data sources are referenced in the Composting methodology section.

With regard to the comment on Line 34, we thank the commenter and have corrected the text accordingly on page 7-54.

With regard to the comment on Line 38-41, the national inventory does use the Facts & Figures reports and convert the units from short tons to metric tons. As stated above the Facts & Figures 2018 data were published in November 2020, after the 1990-2019 Inventory was released for Expert Review. The 2018 data from the latest Facts & Figures report has now been included, and data for 2019 (which is extrapolated using 2018 data and population growth) has also been updated.

Lines 38-41 discussed a BioCycle report that notes the number of states that responded to a survey. We believe this type of facility-specific information is useful for context at the state level, which the Facts & Figures reports do not address. We replaced the survey data with text on the Facts & Figures data and total amount of food waste that is nationally diverted to be consistent with the data sources we are using in the actual emission estimates.

Comment 28: 2018 Facts and Figures Report, Page 7-49
Line 24-26- please use the 2018 Facts and Figures and 2018 Wasted Food Report data for composting.

Response: Please see response to comment #27 above.

Comment 29: Miscellaneous Comments on Page 7-50
Recalculations discussion starting on line 11- please use the 2018 Facts and Figures and 2018 Wasted Food Report data for composting.

Line 29- Planned Improvements- does the WARM data on composting help? EPA contact: wittstruck.nathan@epa.gov

Line 34- I would be very interested in the results of this research, we could incorporate it into the EPA's Excess Food Opportunities Map, which already includes over 3000 composting facilities in it.

Response: Please see response to comment #27 regarding use of the latest Facts & Figures Report.

With regard to the comment on Line 19, we have been considering breaking composting into 2 categories (the same categories as WARM) as a future improvement. The WARM model uses as its CH_4 emission factors: 0.0055 $MTCO_2e$/ton for biowaste, and 0.0139 $MTCO_2e$/ton for green waste. Same for the N_2O emission factors. The inventory uses one CH_4 and N_2O emission factor for all waste composted but could estimate emissions separately for food waste and yard trimmings because data for these 2 sources are included in the Facts and Figures report, with more detail on food waste now. We plan to run the calculations internally and compare using the estimates using the WARM emission factors as a future planned improvement.

With regard to the comment on Line 34, this comment is in response to the Planned Improvements about incorporating composted amounts from facilities in PR and territories. EPA will plan to share data found as a result of this research and will review how to incorporate this data into future inventory cycles since the Facts & Figures reports do not appear to address material pathways in the U.S. territories or Puerto Rico.

Comment 30: EPA Facts and Figures Report, Annex Section 3.14
Page A-67- Starting on line 15- Just noting that you don't use EPA's Facts and Figures Report- why? Seems odd not to use EPA's data in another EPA report.

Response: The commenter is correct, for landfilling we have used the BioCycle and other bottom-up type data versus the Facts & Figures reports. The main reason is that we have always tried to use a bottom up approach, which equates to a higher tier methodology under the IPCC framework. IPCC encourages use of facility-specific data to the extent possible and the BioCycle surveys provide more detail at the state level compared to the Facts and Figures report. The total amount of waste generated data is only used for 1990-2004 in the time series, and then a different methodology is used for the 2005 to 2019 time series. The Facts & Figures data will also be referenced as a part of QA/QC procedures, but note that comparisons of the total amount of waste landfilled as estimated by the Facts & Figures data and the Greenhouse Gas Reporting Program for MSW landfills (subpart HH, which only includes a subset of all MSW landfills) indicates that the Facts & Figures reports may be underestimating the total amount of waste landfilled.

Comment 31: Correction to waste characterization
Annex Section 3.14, Page A-69- Box A-1- 2nd par.: "Discarded or landfilled material is Subtitle D waste only and assumed to be the calculated difference between generation and recovery through recycling and composting (EPA 2019a)." This is not quite accurate: generation minus recycling minus composting = landfill + combustion. 19.6% of generated MSW that was not recycled or composted was combusted with energy recovery, except for major appliances, tires, and lead-acid batteries and food. This estimate was derived from the Energy Recovery Council's (ERC) Directory of Waste-to Energy facilities (ERC, 2018). In other words, of the waste not handled by recycling and composting, 19.6% was combusted and 80.4 was landfilled (except for the materials mentioned above).

Response: EPA appreciates this clarification. Revisions have been made in Annex 3.14 of the final 1990-2019 Inventory.

Comment 32: Reasons for treating wastewater
p. 7-17, lines 4-5: it could be mentioned that water is also treated to remove nutrients

Response: EPA appreciates the feedback. This edit has been made to the chapter text on page 7-21

Comment 33: N_2O described as intermediate of nitrification
p. 7-17, lines 34-40: Not sure that N_2O should be considered an intermediate of nitrification, but rather (as it is listed in p. 7-42, line 7) as a by-product.

Response: The text of this chapter has been edited to reflect changes based on this comment on page 7-21.

Comment 34: Stripping of N_2O during aeration
p. 7-17 lines 39-40: This matches well with literature I read related to N_2O emissions (Law et al, 2012, Nitrous oxide emissions from wastewater treatment processes ; Ahn et al. 2010, N_2O emissions from activated sludge processes, 2008-2009).

Some cases of stripping in turbulent areas (where the turbulence is not caused by aeration) has also been noted, but this is likely below the level of significance.

Response: The text of this chapter has been edited to reflect changes based on this comment regarding stripping.

Comment 35: Change "systems" to plural
p. 7-34, line 42, word 1: systems (plural)

Response: This edit has been made to the chapter text on page 7-38.

Comment 36: Wording of sentence about methodological equations
p. 7-35, lines 5-6: I presume this is intended to read similarly to p. 7-20 lines 6-7, as "Methodological equations for each of these systems are presented in the subsequent subsections; total domestic N2O emissions are estimated as follows:"

Use of "however" seems fine if that is what is intended, but without "each of these systems are" the meaning of this sentence is unclear.

Response: This edit has been made to the chapter text on page 7-39.

Comment 37: Equation for total nitrogen entering septic systems
p. 7-35, lines 23-24: This equation is slightly hard to follow because the units are not defined until p. 7-36 (the following page, halfway down).

Response: This equation has been moved in the chapter text to be more reader friendly, see page 7-40.

Comment 38: Lack of clarity in sentence about N_2O emissions from POTWs

p. 7-37, lines 8-11: this sentence is a bit hard to follow due to its length. The presence of the parenthetical "(other than constructed wetlands)" breaks the flow and makes it a bit harder to follow that this is the "relative percentage of wastewater treated by [all the systems]"

This is similar for all long sentences explaining what is multiplied. Clarity could potentially be improved.

Response: EPA appreciates this comment however changes were not made to the text. We will consider clarity changes as part of planned improvements.

Comment 39: Table 7-18 formatting
p. 7-40, Table 7-18: this is purely formatting related/stylistic, but it seems that the table 7-18 could have the 3rd column widened so that the 3rd column header only takes up 2 lines of space instead of 4.

Response: EPA has implemented this formatting change to the chapter text.

Comment 40: Parentheses typo in equation description
p. 7-40, lines 8-11: There are two start parenthesis with no end parenthesis. There seems to be repetition of "total nitrogen in centrally treated wastewater".

Because there is no end parenthesis for "one minus the fraction....", this makes the description of the equation below unclear.

Response: EPA did make edits to the relevant chapter text in response to this comment on page 7-45.

Comment 41: Equation split across two pages
p. 7-40, line 20 & 7-41, line 1: This is purely stylistic/formatting, but it is preferable to keep the full equation on one page and not split across two pages.

Response: EPA has implemented a formatting change to the chapter text to address this comment, see page 7-45 and 7-46.

Comment 42: Unclear table footnote on page 7-41
p. 7-41, line 5: This note is not clear in its meaning

Response: EPA is reviewing the footnote for clarity and no edit has been made in the chapter text in response to this comment. We will consider future edits as appropriate.

Comment 43: Grammatical correction
p. 7-41, line 7: "were added to" (tenses should agree)

Response: EPA has implemented the edit has been made the chapter text in response to this comment on page 7-46.

Comment 44: Wording of sentence about N_2O emissions from aerobic treatment systems
p. 7-42, line 8: I would have to disagree with the wording of this statement (there is also a missing space between N_2O and emissions). If N_2O is generated by denitrification, anaerobic systems would also result in N_2O production and non-zero emissions (though likely negligible for calculations).

Per the earlier statement on N_2O stripping (p. 7-17, lines 39-40), N_2O is primarily stripped and therefore emitted from aerated treatment processes. The use of "primarily" is preferrable to the use of "only".

As accounted for on page 7-43, N_2O that is not stripped from treatment processes must either be converted to N_2 by microorganisms or else released as emissions after being discharged from the treatment plant.

Response: EPA has implemented edits to the chapter text in response to this comment on page 7-47.

Comment 45: Match variable description and units
p 7-42, line 19: wording and units should match. Clarify if this is per unit of product or per inventory year.

Response: EPA has implemented edits to the chapter text in response to this comment on page 7-47.

Comment 46: Grammatical correction on page 7-42
p. 7-42, line 24: propose to include a comma after "Table 7-10"

Response: An edit has been made to the chapter text in response to this comment on page 7-47.

Comment 47: Unclear description of industries with available data for 2018
p. 7-44, line 7: Makes this sound as though these separate industries are one combined processing industry, slightly unclear.

Response: Edits have been made to the chapter text in response to this comment on page 7-49.

Comment 48: N Effluent heading on Table 7-21
p. 7-44, Table 7-21: Was it specified per what unit these kg N are discharged? Was this the net total for 2018?

Response: Edits were made to the title of the table in response to this comment, see Table 7-38 on page 7-49.

Comment 49: Meaning of sentence about input variables used in uncertainty analysis
p. 7-44, line 18: Propose to remove comma between "wastewater" and "and wastewater".

However, I may misunderstand this sentence. Are the uncertainties in "the numerous variables used to model emissions from domestic wastewater and [emissions from] wastewater from pulp..." or are the uncertainties in "the numerous variables used to model emissions from domestic wastewater, and [in the volumes of(?)] wastewater from pulp..." ?

Response: Clarifying edits were made to the chapter text in response to this comment on page 7-49.

Comment 50: Grammatical correction on page 7-46
p. 7-46, line 11: propose "updates to organics removed and emissions discharged" (verb tenses do not currently match)

Response: Clarifying edits made to the chapter text in response to this comment on page 7-51.

Comment 51: Listed order of percent increases
p. 7-46, lines 21-23: In all other paragraphs the smallest increase is listed before the largest increase. In this case the largest is listed first, followed by the smallest (which is also labeled as the largest).

Response: EPA did make edits to the referenced chapter text in response to this comment on page 7-52.

Comment 52: Grammatical correction on page 7-47
p. 7-47, line 4: propose comma between "domestic" and "the". Inclusion of the word "sources" alongside "domestic" and "industrial" (in line 5) could further improve clarity.

Response: EPA did make clarifying edits to this section of chapter text in response to this comment on page 7-52.

Comment 53: General comment on wastewater estimates
The wastewater section of the Inventory is clearly written and demonstrates EPA's understanding of domestic wastewater treatment processes. This section defines the boundaries of the emissions estimates, with the sources and offsets that are included in the estimates. NACWA appreciates that EPA has followed the Association's previous recommendation that the calculation variables and data sources be presented in table form.

Response: EPA appreciates the commenter's feedback.

Comment 54: Minor errors in wastewater section
Two small errors should be corrected in the wastewater section. First, "biosolids" are distinct from "sludge," per EPA regulations. The term "sludge" should therefore not be placed in parentheses after "biosolids" on page 7-22. Second, the equation on page 7-25 showing the biogas production appears to be missing the term "population," which should be multiplied by the biogas generation rate.

Response: EPA appreciates the feedback. Clarifying edits, including the addition of a footnote (p. 7-26), have been made to section 7.2 of the Waste chapter text in response to this comment.

Comment 55: Thoughts on disaggregating national estimates
EPA asked for comment on the disaggregation of national estimates and the availability of disaggregated data, such as at the state level. This would require emissions calculation methods other than the IPCC methods, since the IPCC methods are based largely on population and on estimates of nitrogen and biological oxygen demand (BOD) loading per capita. Some utility-level and state-level data is available, but there is a need for more data to be collected. Although consideration of data at a more granular level is preferable, it must also be used carefully when drawing conclusions at a broader level.

Response: EPA appreciates the commenter's feedback and will consider it in future work on disaggregating national estimates for wastewater treatment emissions.

Comment 56: EPA incorporation of IPCC refinements
The calculations from the IPCC Refinement are based entirely on influent nitrogen loading and do not account for whether POTWs have nitrification/denitrification processes at the treatment plant. Nitrous oxide cannot form without nitrification and/or denitrification occurring. However, as the calculations are

set up, the emission estimate is the same for a plant with nitrification/denitrification as for a plant without nitrification/denitrification.

Previous IPCC guidance used population as the basis for nitrous oxide calculations, as does the current IPCC Refinement. However, the previous IPCC guidance used different emissions factors depending on whether plants use nitrification/denitrification processes, with lower emissions resulting from plants without nitrification/denitrification. The IPCC calculations for nitrous oxide should account for the presence or absence of nitrification/denitrification processes at different treatment plants.

Actual nitrous oxide emissions are likely very process-specific, with factors such as consistency of dissolved oxygen levels, system upsets, and supplemental carbon addition sources potentially playing a large role in the quantity of nitrous oxide formed. Further refinements will be needed in the future with respect to treatment process type.

Response: The 2006 IPCC Guidelines provided a methodology to estimate nitrous oxide emissions for "advanced centralized wastewater treatment plants with controlled nitrification and denitrification steps." This methodology was based on one study from a small system in the northern U.S. The guidance did not provide a methodology or emission factor for any other type of centralized wastewater treatment plant, which effectively resulted in their emissions being not included in the inventory.

The 2019 IPCC Refinement to the 2006 IPCC Guidelines evaluated more recent research and field studies regarding nitrous oxide emissions from all categories of centralized aerobic wastewater treatment (i.e., activated sludge and its variants). Some of these systems included "controlled nitrification and denitrification steps" and are identified in the Annex 6A.5 as "Biological Nitrogen Removal" or (BNR) systems. Other systems were non-BNR, most of which do not have a specific denitrification step. The authors found that nitrous oxide emissions correlated with influent nitrogen load and that although nitrous oxide emissions vary by the type of nitrogen removal process used, there were insufficient data to develop unique emission factors for these different treatment processes.

Nitrous oxide is generated as a by-product of nitrification, or as an intermediate product of denitrification. Studies showed that nitrous oxide emissions could occur prior to the secondary treatment step (i.e., biological treatment). When measured, nitrous oxide emissions could be detected from influent wastewater that was treated through grit removal and primary settling, likely from dissolved nitrous oxide in the influent wastewater. Studies also found that dissolved nitrous oxide was emitted in aeration steps, wherever they occurred in the system. Emissions in sewer networks and from nitrification or nitrification-denitrification processes at wastewater treatment plants, previously judged to be a minor source, may in fact result in more substantial emissions. Therefore, it is appropriate to include an estimate of emissions from all categories of centralized aerobic treatment systems, not just those with denitrification processes.

As stated by the commenter, there are many factors affecting nitrous oxide emissions from wastewater treatment systems such as the temperature and dissolved oxygen concentration of the wastewater, and the specific operational conditions. EPA agrees that development of more specific emission factors based on type of system would be an improvement and will continue to evaluate available data. EPA is unlikely to develop emission factors that vary based on specific operating

parameters at the more than 16,000 centralized treatment plants in the U.S. as we lack activity data to appropriately use such factors.

Comment 57: Input on data used in emission estimates
Developing US-specific methods for estimating nitrous oxide emissions, rather than using IPCC methods, should a priority for EPA. It would likely be more accurate to have different default factors for the type of treatment processes applied, such as nitrification/denitrification, rather than using the IPCC default factor for domestic wastewater of 0.005 kg N_2O-N/kg N. During the public comment period, NACWA will provide additional information on this factor, as well as the emission factor for nitrogen from industrial and commercial sources co-treated with domestic wastewater.

We recommend that additional consideration be given to where wastewater discharges occur in the aquatic environment. The current emissions factors apply to "estuaries," but further details describe "slow moving" aquatic systems. A large portion of wastewater discharges go to aquatic systems that are not "slow moving," since discharge points for POTWs are usually selected to meet water quality objectives and to target dilution and movement of the receiving water – conditions that are not conducive for producing GHG emissions. A better understanding of how emissions depend on the discharge points would likely lead to more accurate emissions estimates.

Response: EPA appreciates commenter's feedback and looks forward to additional, more detailed comments on a subsequent draft of this report.

The commenter specifically references the default emission factor of 0.005 kg N_2O-N/kg N. This factor applies only to wastewater effluent discharged to surfaces waters not impaired for nutrients and, as noted in 2019 IPCC Refinement, does take into consideration assumptions about nitrification/denitrification within the waterbody where the effluent is discharged. The default emissions factor for wastewater effluent discharged to impaired waters is 0.019 kg N_2O-N/kg N, which is also used in the U.S. Methodology.

The commenter requests the use of different emission factors for the discharge from centralized wastewater treatment to account for different treatment processes in place. It is unclear exactly what the commenter is suggesting, but the degree to which nitrogen is removed from the system prior to discharge is estimated based on whether the system achieves only primary treatment (i.e., settling, but no biological treatment), secondary treatment (i.e., biological treatment with no designed advanced nutrient removal), or tertiary treatment (i.e., biological treatment with nutrient removal).

The commenter also requests consideration for emissions associated with discharge to the aquatic environment. For nitrous oxide emissions, the IPCC Tier 3 emission factor is applied to discharges to waterbodies that are impacted for nutrients. The IPCC Tier 1 emission factor is applied to all other wastewater discharges. For methane emissions, the two IPCC Tier 2 emission factors are used for discharges to reservoirs, lakes, and estuaries (0.114 kg CH_4/kg BOD) and all other discharges (0.021 kg CH_4/kg BOD). EPA acknowledges that the approach used to determine the approximate percent of waterbodies that are reservoirs, lakes, or estuaries was a high-level investigation and based on limited data and data sources. If the commenter is aware of a source that provides a quantitative estimation of POTW wastewater effluent discharged to the various waterbody types to provide context to a "large portion of wastewater" discharged to "not slow moving" aquatic system, EPA encourages the commenter to provide that source to further improve methane emissions estimates.

Comment 58: General comment on wastewater treatment emissions sources and offsets
We agree with EPA's planned improvements for the Inventory and encourages development of US-specific methodologies and emission factors when appropriate. We also suggest that EPA provide diagrams showing emissions sources and offsets related to each process stage in the domestic wastewater treatment train. This would provide context of the function and objective of POTWs to protect public health and water quality through wastewater treatment.

Response: EPA appreciates the commenter's feedback and will consider whether there are data sufficient to develop U.S.-specific methodologies and factors. EPA will also consider whether additional discussion of emission sources is warranted. The inventory is a policy-neutral, technical report providing information on current GHG emissions and sinks and trends prepared per reporting UNFCCC Annex 1 National GHG Reporting Guidelines (see Box ES-1) and as such, it is not well-suited as a document in which to outline mitigation opportunities or examples of how different treatment trains may or may not behave. EPA will also consider whether additional discussion of emission sources is warranted. As the commenter noted in comment 60, the amount of nitrous oxide emissions (and EPA adds methane emissions) that occur for a specific system or process are dependent on several operating variables.

Comment 59: Distinguishing between BOD and BOD_5
Page 7-18, lines 16-20, and later parts of the chapter. The text should make it clear when it is referring to BOD_5. For example, page 7-18, lines 16-19, refers to ultimate BOD: "BOD represents the amount of oxygen that would be required to completely consume the organic matter . . .". But the following lines introduce BOD_5. Then, in the remainder of the chapter, the term BOD is used when referring to BOD_5. While it is unlikely that professionals working in the field will be confused by this, some editing will avoid ambiguity. One solution would be to include a note (or footnote) around line 20 on page 7-18 stating that "BOD" means BOD_5 throughout the remaining text. Alternatively, where specific values of BOD_5 are cited (e.g. in Table 7-11 on page 7-29), or factors are presented that depend on using BOD_5, the text could refer specifically to BOD_5.

Response: EPA appreciates the comment submitted and has added a note at the first reference to BOD indicating that throughout the chapter, the term "BOD" refers to BOD_5.

Comment 60: Include main formula variables in table
Page 7-22, line 22 ff., and elsewhere. The title of a formula is presented and then the first variable in the formula is what the title is referring to. For example, at line 22, "Organic component removed from aerobic wastewater treatment" is followed by "$S_{aerobic}$ =". The formula is followed by a table defining the remaining variables. It would be clearer if the main variables (e.g. $S_{aerobic}$) were also included in the tables since that is where all the other variables are listed.

Response: EPA appreciates this comment and has edited the tables in the document according to the commenter's suggestion.

Comment 61: Accessibility of references
Page 7-55 ff. References. (Also applies to Annex references.) Accessibility to references can be improved,. To the extent practical, sources should be available online, and a URL to the documents should be included in the references section. This is especially important for sources that are not readily available through normal research channels, e.g. contractor reports. For example, ERG references do not turn up in web searches or through the EPA home page search bar, and there is no search function

on the erg.com home page. Because the inventory report relies heavily on such sources, verifiability and understanding will benefit by providing greater access. If material is proprietary and cannot be made public, that needs to be made clear in the text.

Response: EPA appreciates the feedback. We will assess the feasibility to publish original references in a more accessible and usable format with forthcoming Inventory publications. Full citations for all references cited in the report can be found in Chapter 10 of the report for full transparency.

Comment 62: CH_4 emissions from collection system

One reaction that I have is that, while the document does acknowledge CH4 emission from the collection system, this does not seem to be estimated. This would seem to be a very large portion of the overall emissions, depending on the physical characteristics of the catchment.

Response: EPA thanks the commenter and believes the commenter is correct that emissions from collection systems are not explicitly covered, yet we believe a component of those emissions are captured by the new centralized treatment plant emission factor. We plan to explore this further for potential inclusion in a future Inventory report.

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: 1990-2019* to a list of 7 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.

- Kartik Chandran – Columbia University
- R. Christopher Barry – New Jersey Department of Environmental Protection (DEP)
- Claudia Fabiano – EPA, Sustainable Management of Food (Office of Resource Conversation and Recovery/Office of Land and Emergency Management)
- Shanna Myers – Murraysmith
- Cynthia Finley – National Association of Clean Water Agencies (NACWA)
- Alcoa (sent by Luis H. Espinoza-Nava, Alcoa Technical Center)
- Charles Bott – Hampton Roads Sanitation District

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

Appendix B: Dates of Review

- Energy: October 27 – November 30, 2020
- Industrial Processes and Product Use (IPPU) : October 27 – November 30, 2020
- Waste: October 20 – November 19, 2020
- Agriculture: October 20 – November 19, 2020
- Land Use, Land Use Change and Forestry (LULUCF): December 17, 2020 – January 18, 2021

Appendix C: EPA Charge Questions to Expert Reviewers

To facilitate expert review and indicate where input would be helpful, the EPA included charge questions for the Expert Review Period of the draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019* report. EPA also noted to expert reviewers that while these charge questions were designed to assist in conducting a more targeted expert review, comments outside of the charge questions were also welcome. Included below is a list of the charge questions by Inventory chapter.

Energy

Requests for Expert Feedback for the 1990-2019 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.

Source-Specific Questions:

Fossil Fuel Combustion: CO_2 from Fossil Fuel Combustion

1. Please provide your overall impressions of the clarity of the discussion of trends in CO_2 emissions from fossil fuel combustion. Please provide recommendations for any information that could be added to the discussion to provide additional transparency and clarity.
2. Data for energy use in U.S. Territories comes from updated International Energy Statistics provided by EIA. Are the updates adequately described and do they compare to any other sources of U.S. Territory energy use that could be used?
3. Facility-level combustion emissions data from EPA's GHGRP are currently used to help describe the changes in the industrial sector. Are there other ways in which the GHGRP data could be used to help better characterize the industrial sector's energy use? Are there ways the industrial sector's emissions could be better classified by industrial economic activity type?

Fossil Fuel Combustion: CH_4 and N_2O from Stationary Combustion

1. The CH_4 and N_2O emission factors for the electric power sector are based on a Tier 2 methodology, whereas all other sectors utilize a Tier 1 methodology. For all other stationary sectors, the emission factors used in Tier 1 methods are primarily taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Are there other more U.S.-specific CH_4 and N_2O 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.

Industrial Processes and Product Use (IPPU)

Requests for Expert Feedback for the 1990-2019 IPPU Chapter

General Questions:

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

Source-Specific Questions:

Minerals

1. **Glass Production** - Please provide data and/or information on data sources on limestone, dolomite, and soda ash (carbonates) used for glass manufacturing, nationally and by state.
2. **Other process uses of carbonates** - Please provide data and/or information on carbonate use nationally and by state in production of:
    - non-metallurgical magnesium.
    - ceramics.

Chemicals

3. **Ammonia Production and Urea Consumption for Non-Agricultural Purposes -** Please provide data and/or information on data sources that provide disaggregated data for 1990-2019 by U.S. state or region.
4. **Glyoxal and Glyoxylic Acid Production** - Please provide feedback on production data and/or information on data sources of glyoxal and glyoxylic acid, nationally and disaggregated by state for 1990-2019.
5. **Calcium Carbide Production** - Please provide information on availability of data on calcium carbide production or petroleum coke used in calcium carbide production, and on calcium carbide used in the production of acetylene used for welding applications to estimate emissions using IPCC methods for 1990-2019.
6. **Phosphoric Acid Production**-Please provide feedback on data sources and assumptions, including:
    - The use of regional production capacity from 2005 to 2011 to estimate regional production from 2005 to 2019.
    - The carbonate composition of phosphate rock and how it varies depending upon where the material is mined and over time.
    - The disposition of the organic carbon content of the phosphate rock and the assumption that it remains in the phosphoric acid product and is not released as CO_2. This includes feedback on the assumption that all domestically produced phosphate rock is used in phosphoric acid production and it is used without first being calcined.

Metal Production

7. **Iron and Steel Production** – Please provide data and/or information on data sources for production of iron and steel by state or region for 1990-2019.
8. **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 2019.
    - Data and/or information on data sources on production of ferroalloys by state for 1990-2019.
9. **Aluminum Production –** Please provide feedback on following updates:
    - This is the first year that Low Voltage Anode Effect (LVAE) emissions of CF4 were estimated for 2006-2019 based on the Tier1 (technology specific, production-based) method in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Please provide any recommendations to improve the clarity and/or accuracy of the LVAE estimation methods.
    - The 2019 IPCC Refinement updated the technology types used for determining technology specific default emission factors, providing three Point-Fed Prebake (PFPB) technologies in place of the previous Center-Work Prebake class in the 2006 IPCC guidelines (See Annex 1 for copy of Table 4.15 from the 2019 IPCC Refinement).
        - Do you agree with the methodology of using the legacy PFPB (PFPB-L) emission factor for the calculation of LVAE emissions in place of CWPB for U.S. smelters?
        - Do you concur that there are no modern PFPB (PFPB-M) facilities in the United States?

10. **Lead Production** – Please provide data and/or information on data sources on primary and secondary production of lead by state for 1990-2019.
11. **Zinc Production** – Please provide feedback on:
    - Data and/or information on data sources on primary and secondary production of zinc by state for 1990-2019.
    - The application of assumptions to determine the split between primary and secondary zinc production based on U.S. Geological Survey national totals. Are other options/data sources available to distinguish between process production totals?

Other IPPU Categories

12. **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 Greenhouse Gas Reporting Program (GHGRP).

13. **Nitrous Oxide from Product Uses** – Please provide feedback or data and/or information on data sources on nitrous oxide production, market share of end uses, and the emission factors for each end use for 1990-2019, nationally and by state.

Agriculture

Requests for Expert Feedback for the 1990-2019 Agriculture Chapter

General Questions:

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

Source Specific Questions:

1. For the Manure Management source category, is the state of the industry current accurately described? Are there other technologies, practices, trends that we should consider?
2. Are the parameters and discussion of uncertainty within the Manure Management source category estimates adequately reflecting all uncertainties from this industry and the data EPA is currently using?
3. The Manure Management source category relies on national/regional livestock production and management data for calculating emissions estimates from USDA APHIS and NASS. Are there other/newer data sources that EPA should be aware of and consider in the calculating these emissions? Especially for:
    - Waste management system data, particularly seasonal changes in emissions from different WMS;
    - Maximum methane producing capacity;
    - Volatile solids and nitrogen excretion rates;
    - Measured emission estimates (by waste management system) to help refine estimates of methane conversion factors.
4. For the Enteric Fermentation source category, is the state of the industry current and accurately described? Are there other technologies, practices, trends that we should consider?
5. The Enteric Fermentation source category relies on national/regional livestock production, diet and management data for calculating emissions estimates. Are there other/newer data sources or methods that EPA should be aware of and consider in the calculating these emissions? Especially for:
    - Dry matter/gross energy intake;
    - Annual data for the DE, Y_m, and crude protein values of specific diet and feed components for foraging and feedlot animals;
    - Monthly beef births and beef cow lactation rates;
    - Weights and weight gains for beef and dairy cattle.
6. For the Enteric Fermentation source category and the Cattle Enteric Fermentation Model (CEFM), are the various regional designations of U.S. states (as presented in Annex 3.10) used for characterizing the diets of foraging cattle appropriate? The CEFM is used to estimate cattle CH_4 emissions from enteric fermentation, and incorporates information on livestock population, feeding practices, and production characteristics.

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

Waste

Requests for Expert Feedback for the 1990-2019 Waste Chapter

General Questions:

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).
3. We are exploring disaggregation of national estimates and are interested in understanding the availability of more disaggregated data (e.g. state level), in particular for industrial landfills, industrial wastewater, and composting.

Wastewater Specific

1. As stated in our Recalculation Discussion, EPA incorporated refinements based on IPCC's *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/)*. Are there any considerations on the recalculations that you would like to bring to our attention, or other refinements that should be included?
2. For domestic wastewater emissions, please provide input on:
    a. Any additional sources for the N content of sludge, amount of sludge produced, and sludge disposal practices,
    b. National level data on the type of wastewater treatment systems in operation,
    c. Whether the state of domestic wastewater treatment is current and accurately described,
    d. National level data on the biogas generation and recovery operations,
    e. The estimates of the percent of BOD or N removed by aerobic, anaerobic, and other treatment systems,
    f. The protein estimates and overall calculations for nitrous oxide. For example, do you have suggestions for developing a country-specific factor, rather than the IPCC default factor, to estimate the amount of nitrogen from industrial and commercial sources co-treated with domestic wastewater,
    g. Sources of data for development of a country-specific methodology for N_2O emissions associated with on-site industrial wastewater treatment operations, including the appropriateness of using IPCC's default factor for domestic wastewater (0.005 kg N_2O-N/kg N), and
    h. Any additional sources for where domestic wastewater discharges occur in the aquatic environment.

3. For industrial wastewater emissions, please provide input on:
    a. Any additional sources of wastewater outflow, BOD generation, N entering treatment, BOD discharged, or N discharged for industries included in the inventory,
    b. National level data on the type of wastewater treatment systems in operation for industries included in the inventory,
    c. National level data on the biogas generation and recovery operations for industries included in the inventory,
    d. National or state level production data for industries included in the inventory,
    e. Whether the state of industrial wastewater treatment is current and accurately described,
    f. National level data for biogas generation and recovery operations for industries included in the inventory, and
    g. Any additional sources for where industrial wastewater discharges occur in the aquatic environment.

4. 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?
5. 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?

Landfill Specific

1. Additional information regarding the scale-up factor methodology used within the latter portion of the time series for MSW landfill emissions has been added to the Inventory Annex in response to comments submitted by the UNFCCC and the need to update the scale-up factor based on changes in facility reporting to the Greenhouse Gas Reporting Program. Please comment on the clarity of the scale-up factor methodology, revised value developed for years 2017 to 2019, and application of different scale-up factors over the time series. Please provide information on any portion of the approach that is unclear.
2. Please comment on datasets that detail the quantities of industrial food processing waste that is disposed of in industrial waste landfills. The GHGRP dataset for industrial waste landfills includes a snapshot of select food processing facilities, but vastly underestimates the entire food processing sector. The Inventory methodology applies a disposal factor to the annual amount of foods processed. Currently, we do not have a representative data set for this sector with which to improve the methodology. Please comment and/or provide additional data on whether the findings from recent Food Waste Alliance surveys[1] that approximately 84 percent to 94 percent of food waste from the manufacturing sector is repurposed versus being landfilled is representative of the food and beverage sector.

   We recently reviewed the EPA's 2020 Wasted Food Measurement Methodology Scoping Memo because it includes industrial food waste estimates that will be incorporated into future Advancing Sustainable Materials Management: Facts and Figures reports. The methodology is not clear on the amount of waste from the food and beverage sector that is specifically disposed in industrial waste landfills versus a combination of MSW and industrial waste landfills. Additionally, page xi of the introduction states that the industrial sector will not be included in future reports:

   "EPA will use the enhanced measurement methodology, with one exception, to derive updated estimates of excess food and food waste generation and management for the "Facts and Figures Report" starting with the 2018 estimates, which are anticipated to be published in late 2020. ***The exception is the industrial sector*** *(i.e., food manufacturing/processing), which will not be included in the "Facts and Figures Report". While the food manufacturing/processing sector is an important component of the entire food system,* ***it will not be included in EPA's annual "Facts and Figures Report" because industrial sources of waste are out of scope*** *for the "Facts and*

[1] Analysis of U.S. Food Waste Among Food Manufacturers, Retailers, and Restaurants. The 2016 report is available at < https://foodwastealliance.org/wp-content/uploads/2020/05/FWRA-Food-Waste-Survey-2016-Report_Final.pdf> and the 2014 report is available at < https://foodwastealliance.org/wp-content/uploads/2020/05/FWRA_BSR_Tier3_FINAL.pdf>.

Figures Report". Therefore, the "Facts and Figures Report" will include excess food and food waste generation estimates for the residential, commercial and institutional sectors, and estimates of how much excess food and food waste is managed by the following pathways: animal feed, bio-based materials/biochemical processing, co-digestion/anaerobic digestion, composting/aerobic processes, controlled combustion, donation, land application, landfill, and sewer/wastewater treatment. "

We will review the methodology used in the EPA's scoping memo for industrial waste in more detail and make a determination on the advantages and disadvantages to using the methodology described in the memo in future Inventories. Please comment on the methodology presented in the EPA's Scoping Memo for industrial food waste generation and landfill disposal.

Composting Specific

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

Stand-Alone Anaerobic Digestion Specific

1. Inclusion of emission estimates for stand-alone anaerobic digestion (AD) are new for the 1990-2019 Inventory. 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 and 2016 (US EPA 2018 and 2019[2]). 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.

   Table 1 presents the different average and median values of food waste processed from the 2015 and 2016 surveys. Table 2 presents the estimated count of operational facilities per year and three potential methods to estimate the amount of annual food waste processed. Please see the chapter text for a complete description of the methodology.

   In short, we estimated the operational count of facilities (column 3 in Table 2 below) from a figure in EPA (2019) that shows the count of the first year of operation in the EPA survey report, and then assumed each new facility that started operating in a given year was operational for each subsequent year. This likely overestimates the annual count of facilities per year. We then estimated the annual quantity of waste processed using three different factors (columns 4 to 6 in Table 2) before deciding to use the weighted average of the 2015 and 2016 survey data in the emission estimates.

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[2] US EPA, 2019. Anaerobic Digestion Facilities Processing Food Waste in the United States in 2016: Survey Results. September 2019 EPA/903/S-19/001. Available at < https://www.epa.gov/sites/production/files/2018-08/documents/ad_data_report_final_508_compliant_no_password.pdf>.
US EPA, 2018. Anaerobic Digestion Facilities Processing Food Waste in the United States in 2015: Survey Results. May 2018 EPA/903/S-18/001. Available at < https://www.epa.gov/sites/production/files/2019-09/documents/ad_data_report_v10_-_508_comp_v1.pdf>.

Table 1. Various Activity Data Factors Used to Estimate the Annual Quantity of Waste Processed by Stand-Alone AD Facilities from 1990-2014

Factor Description	Reference	Factor	Units	Notes
2016 median quantity of food waste processed	US EPA 2019, Table 6	48,725	short tons	Assuming short tons; food waste only.
2016 average quantity of food waste processed	US EPA 2019, Table 6	459,267	short tons	Assuming short tons; food waste only.
2016 # of facilities responded to survey	US EPA 2019, Table 6	46		
2015 median quantity of food waste processed	US EPA 2018, Table 3	45,000	short tons	Assuming short tons; food waste only.
2015 average quantity of food waste processed	US EPA 2018, Table 3	251,274	short tons	Assuming short tons; food waste only.
2015 # of facilities responded to survey	US EPA 2018	50		
2015 & 2016 weighted average food waste processed	Calculated	350,937	short tons	Used in the 1990-2019 Draft Inventory emission estimates
2015 & 2016 weighted median food waste processed		46,784.9	short tons	

Table 2. Estimated Quantity of Waste Processed and CH_4 Emitted by Stand-Alone AD Facilities from 1990-2019

1	2	3	4	5	6	7	8
Year	Count of First Year of Digester Operation[1]	Number of Operating Facilities[2]	MT of waste processed (based on 2016 median)	MT of waste processed (based on weighted 2016 and 2015 median)	MT of waste processed (based on weighted 2016 and 2015 average)[3]	kt of waste processed	kt of methane emitted
1990	1	1	44,202.6	42,442.5	318,365.0	350.9	0.3
1991	1	2	88,405.2	84,885.1	636,729.9	701.9	0.6
1992	1	3	132,607.7	127,327.6	955,094.9	1,052.8	0.8
1993	0	3	132,607.7	127,327.6	955,094.9	1,052.8	0.8
1994	1	4	176,810.3	169,770.2	1,273,459.9	1,403.7	1.1
1995	2	6	265,215.5	254,655.3	1,910,189.8	2,105.6	1.7
1996	0	6	265,215.5	254,655.3	1,910,189.8	2,105.6	1.7
1997	0	6	265,215.5	254,655.3	1,910,189.8	2,105.6	1.7
1998	0	6	265,215.5	254,655.3	1,910,189.8	2,105.6	1.7
1999	3	9	397,823.2	381,982.9	2,865,284.8	3,158.4	2.5
2000	0	9	397,823.2	381,982.9	2,865,284.8	3,158.4	2.5
2001	2	11	442,025.8	424,425.4	3,183,649.7	3,509.4	2.8
2002	0	11	442,025.8	424,425.4	3,183,649.7	3,509.4	2.8

1	2	3	4	5	6	7	8
Year	Count of First Year of Digester Operation[1]	Number of Operating Facilities[2]	MT of waste processed (based on 2016 median)	MT of waste processed (based on weighted 2016 and 2015 median)	MT of waste processed (based on weighted 2016 and 2015 average)[3]	kt of waste processed	kt of methane emitted
2003	0	11	442,025.8	424,425.4	3,183,649.7	3,509.4	2.8
2004	2	13	486,228.3	466,868.0	3,502,014.7	3,860.3	3.1
2005	0	13	486,228.3	466,868.0	3,502,014.7	3,860.3	3.1
2006	2	15	530,430.9	509,310.5	3,820,379.7	4,211.2	3.4
2007	0	15	530,430.9	509,310.5	3,820,379.7	4,211.2	3.4
2008	4	19	618,836.1	594,195.6	4,457,109.6	4,913.1	3.9
2009	2	21	707,241.2	679,080.7	5,093,839.6	5,615.0	4.5
2010	3	24	795,646.4	763,965.8	5,730,569.5	6,316.9	5.1
2011	5	29	884,051.5	848,850.9	6,367,299.5	7,018.7	5.6
2012	5	34	1,105,064.4	1,061,063.6	7,959,124.4	8,773.4	7.0
2013	10	44	1,547,090.2	1,485,489.0	11,142,774.1	12,282.8	9.8
2014	6	50	1,679,697.9	1,612,816.7	12,097,869.0	13,335.6	10.7
2015	3	53	9,962,838.0	9,962,838.0	9,962,838.0	10,982.1	8.8
2016	2	55	9,305,143.0	9,305,143.0	9,305,143.0	10,257.2	8.2
2017	0	55	9,305,143.0	9,305,143.0	9,305,143.0	10,257.2	8.2
2018	2	57	9,305,143.0	9,305,143.0	9,305,143.0	10,257.2	8.2
2019	0	57	9,305,143.0	9,305,143.0	9,305,143.0	10,257.2	8.2

[1] Visually estimated from Figure 5 in US EPA 2019.

[2] For 1990 to 2014, this is the cumulative total from the prior year. This assumes all facilities are operating from 1990 to 2014, which is likely an overestimate but does not necessarily translate to an overestimate in the amount of waste processed because a median amount of waste processed for the surveyed facilities is applied to these years.

[3] The weighted average of the 2015 and 2016 quantity of waste processed per facility is recommended for use in the emission estimates.

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 2019 time series.

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

1) Updated Methane and Nitrous Oxide Emission Factors for Nonroad Sources and Onroad Motorcycles
2) Updated Gasoline and Diesel Fuel CO_2 Emission Factors
3) Waste Incineration Data Analysis Proposed Improvements

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2019: Updated Methane and Nitrous Oxide Emission Factors for Nonroad Sources and Onroad Motorcycles

This memo provides research and analyses to support improvements in the transportation and mobilesource component of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* ('Inventory') annual report. Improved methane (CH_4) and nitrous oxide (N_2O) emission factors for nonroad sources and onroad motorcycles are developed using engine certification data compiled by the U.S. EnvironmentalProtection Agency (EPA).

Nonroad Sources

The current methodology used to calculate methane (CH_4) and nitrous oxide (N_2O) emissions from nonroad sources is based on IPCC Tier 3 methodology and emission factors in the revised 1996 IPCC Guidelines[1]. This methodology provides emission factors in terms of grams of CH_4 and N_2O per kilogram(kg) of fuel, and estimates emissions based on nonroad equipment activity data and country-specific technology-based emissions factors. CH_4 emission factors are calculated directly from the nonroad component of EPA's MOVES2014b model[2]. N_2O emission factors are calculated using MOVES-Nonroad activity and emission factors in g/kWh by fuel type from the European Environment Agency. Fuel consumption is calculated with EPA's MOVES2014b model.

The updated methodology discussed below uses emission factors that are developed from annual engine certification data[3] compiled by EPA for nonroad small and large spark-ignition (SI) gasoline engines, compression-ignition diesel engines, off-road motorcycles, SI marine engines, and diesel marineengines.

Source Categories

Various source classification codes (SCCs) from MOVES are combined to determine emission factors forthe categories of nonroad equipment in the analysis, as shown in Table 1.

TABLE 1. MOVES SSCS MAPPED TO SOURCE CATEGORIES

Nonroad Equipment Type	2-stroke Gasoline	4-stroke Gasoline	Diesel	CNG	LPG
Airport Equipment					
Ground Support Equipment		2265008005	2270008005		2267008005
Construction Equipment					
Pavers		2265002003	2270002003		2267002003
Tampers/Rammers	2260002006	2265002006	2270002006		

[1] *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organization for Economic Co-Operation and Development, International Energy Agency.Paris, France. Available at http://www.ipcc-nggip.iges.or.jp/public/gl/invs6a.html.

[2] https://www.epa.gov/moves

[3] https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment

Nonroad Equipment Type	2-stroke Gasoline	4-stroke Gasoline	Diesel	CNG	LPG
Plate Compactors	2260002009	2265002009	2270002009		
Rollers		2265002015	2270002015		2267002015
Scrapers			2270002018		
Paving Equipment	2260002021	2265002021	2270002021		2267002021
Surfacing Equipment		2265002024	2270002024		2267002024
Signal Boards/Light Plants	2260002027	2265002027	2270002027		
Trenchers		2265002030	2270002030		2267002030
Bore/Drill Rigs		2265002033	2270002033		2267002033
Excavators			2270002036		
Concrete/Industrial Saws	2260002039	2265002039	2270002039		2267002039
Cement & Mortar Mixers		2265002042	2270002042		
Cranes		2265002045	2270002045		2267002045
Graders			2270002048		
Crushing/Proc. Equipment	2260002054	2265002054	2270002054		2267002054
Rough Terrain Forklifts		2265002057	2270002057		2267002057
Rubber Tire Loaders		2265002060	2270002060		2267002060
Tractors/Loaders/Backhoes		2265002066	2270002066		2267002066
Crawler Tractor/Dozers			2270002069		
Skid Steer Loaders		2265002072	2270002072		2267002072
Off-Highway Tractors			2270002075		
Dumpers/Tenders		2265002078	2270002078		
Other Construction Equipment		2265002081	2270002081	2268002081	2267002081
Other Underground Mining Equipment			2270009010		
Other Oil Field Equipment		2265010010	2270010010	2268010010	
Construction Trucks					
Off-highway Trucks			2270002051		
Farm Equipment					
2-Wheel Tractors		2265005010	2270005010		
Agricultural Tractors		2265005015	2270005015		
Combines		2265005020	2270005020		
Balers		2265005025	2270005025		
Agricultural Mowers		2265005030	2270005030		
Sprayers	2260005035	2265005035	2270005035		
Tillers > 6 HP		2265005040	2270005040		
Swathers		2265005045	2270005045		
Other Agricultural Equipment		2265005055	2270005055	2268005055	2267005055
Irrigation Sets		2265005060	2270005060	2268005060	2267005060

Nonroad Equipment Type	2-stroke Gasoline	4-stroke Gasoline	Diesel	CNG	LPG
Forestry Equipment					
Chain Saws > 6 HP	2260007005				
Shredders > 6 HP		2265007010			
Forest Eqp - Feller/Bunch/Skidder		2265007015	2270007015		
Industrial Equipment					
Aerial Lifts		2265003010	2270003010		2267003010
Forklifts		2265003020	2270003020	2268003020	2267003020
Sweepers/Scrubbers	2260003030	2265003030	2270003030	2268003030	2267003030
Other General Industrial Equip	2260003040	2265003040	2270003040	2268003040	2267003040
Other Material Handling Equip		2265003050	2270003050		2267003050
AC\Refrigeration		2265003060	2270003060	2268003060	
Terminal Tractors		2265003070	2270003070	2268003070	2267003070
Generator Sets	2260006005	2265006005	2270006005	2268006005	2267006005
Pumps	2260006010	2265006010	2270006010	2268006010	2267006010
Air Compressors	2260006015	2265006015	2270006015	2268006015	2267006015
Gas Compressors			2270006020	2268006020	
Welders		2265006025	2270006025		2267006025
Pressure Washers		2265006030	2270006030		2267006030
Hydro Power Units	2260006035	2265006035	2270006035	2268006035	2267006035
Lawn & Garden Equipment (Commercial)					
Lawn mowers		2265004011			
Rotary Tillers < 6 HP	2260004016	2265004016			
Chain Saws < 6 HP	2260004021				
Trimmers/Edgers/Brush Cutter	2260004026	2265004026			
Leafblowers/Vacuums	2260004031	2265004031	2270004031		
Snowblowers	2260004036	2265004036	2270004036		
Rear Engine Riding Mowers		2265004041			
Front Mowers		2265004046	2270004046		
Shredders < 6 HP		2265004051			
Lawn & Garden Tractors		2265004056	2270004056		
Chippers/Stump Grinders		2265004066	2270004066		2267004066
Commercial Turf Equipment	2260004071	2265004071	2270004071		
Other Lawn & Garden Eqp.		2265004076	2270004076		
Lawn & Garden Equipment (Residential)					
Rotary Tillers < 6 HP	2260004015	2265004015			
Chain Saws < 6 HP	2260004020				
Trimmers/Edgers/Brush Cutter	2260004025	2265004025			

Leafblowers/Vacuums	2260004030	2265004030			
Snowblowers	2260004035	2265004035			

Nonroad Equipment Type	2-stroke Gasoline	4-stroke Gasoline	Diesel	CNG	LPG
Lawn & Garden Tractors		2265004055			
Lawn mowers		2265004010			
Other Lawn & Garden Equip.		2265004075			
Rear Engine Riding Mowers		2265004040			
Rail Equipment					
Railway Maintenance		2285004015	2285002015		2285006015
Recreational Equipment					
Motorcycles: Off-Road	2260001010	2265001010			
Snowmobiles	2260001020				
ATVs	2260001030	2265001030			
Golf Carts		2265001050			
Specialty Vehicles/Carts	2260001060	2265001060	2270001060		2267001060
Ships and Boats					
Inboard/Sterndrive		2282010005	2282020005		
Outboard	2282005010		2282020010		
Personal Water Craft	2282005015				

MOVES Calculations

The MOVES2014b model was run for calendar year 2019 for all equipment types. The following modeloutputs were binned by SCC and horsepower bin:

- Equipment Population (Pop)
- Average Horsepower (HP_{ave})
- Load Factor (LF)
- Annual Activity in Total hours (Hr)
- Total Fuel Consumption in grams (Fuel)
- Methane emissions in grams (CH_4)

Average horsepower is converted to average kilowatts (kW) using the conversion factor 0.7457 kW perhorsepower.

Current Emission Factors

In the current methodology, nonroad methane emissions are taken directly from MOVES. Nonroad nitrous oxide emissions are calculated by applying emission factors (EF) in terms of grams per kilowatthour (g/kWh) to the MOVES2014b output as follows:

$$N_2O(g) = HP_{ave} \times 0.7457\ kW/hp \times LF \times EF \times Hr$$

Emission factors come from the European Environment Agency (EEA) Air Pollution Inventory Guidebook[4] and are reproduced in Table 2.

TABLE 2. N_2O EMISSION FACTORS IN G/KWH

Engine Type	N_2O
2-stroke Gasoline	0.010
4-stroke Gasoline	0.030
Diesel	0.035
LPG	0.050

EEA factors are described as "*data set based on engineering calculations from one source; data set(s) based on engineering judgment; data set(s) with no documentation provided; may not be considered representative of the total population.*" EEA also states that "*the applied emission factors for the individual sub-categories should not differ by more than a factor of 2 from the all-country mean*." These N_2O emission factors are used to calculate new emission factors in terms of g/kg fuel for the U.S. based on the 2006 IPCC Tier 3 guidance using EPA's MOVES model.

Nonroad motorcycles and ATVs are treated differently in MOVES. Instead of calculating emissions based on HP, LF and Hr as described above, MOVES provides activity in miles. Since there are no published N_2O emission factors specifically for nonroad motorcycles, the N_2O emission factors used in the current inventory are taken from non-catalyst onroad motorcycles.

$$N_2O(g) = \text{Total Miles} \times EF$$

The N_2O emission factor used in the current inventory for nonroad motorcycles and ATVs is shown inTable 3.

TABLE 3. N_2O EMISSION FACTORS FOR MOTORCYCLES AND ATVS IN GRAMS PER MILE

Engine Type	N_2O
Gasoline	0.007

EEA does not list N_2O emission factors for CNG equipment. Since onroad emission factors for N_2O are similar for both CNG and LPG, the LPG emission factor was used for CNG.

Proposed Emission Factors (g/kWh)

Proposed emission factors in terms of grams per kWh to replace those listed in Table 2 were developed using certification data compiled by EPA. Certification data for small nonroad spark-ignited engines[5],

[4] *EMEP/EEA air pollutant emission inventory guidebook — 2009, European Environment Agency, update June 2010. Available at* http://eea.europa.eu/emep-eea-guidebook.

[5] https://www.epa.gov/sites/production/files/2020-01/small-nonroad-spark-ignition-2011-present.xlsx

large nonroad spark-ignited engines[6] and nonroad compression-ignition engines[7] were mined for N_2O and CH_4 test results. Those data were binned by MOVES horsepower bins and by fuel type. MOVES was used to estimate the engine population for each horsepower bin and fuel type, and population was used to weight the bin-averaged emission results. The newly calculated emission factors ('proposed') are shown in Table 4 and are compared against the Inventory's current emission factors that were obtained from EEA.

TABLE 4. FUEL BASED EMISSION FACTORS FROM CERTIFICATION DATA

Fuel Type	g/kWh			
	CH_4		N_2O	
	Current	Proposed	Current	Proposed
Gasoline 2-stroke	3.040	1.654	0.010	0.046
Gasoline 4-stroke	0.919	0.462	0.030	0.254
Diesel	0.015	0.070	0.035	0.065
CNG	3.676	0.707	0.050	0.011
LPG	0.047	0.054	0.050	0.077

Nonroad motorcycles and ATVs are calculated separately, as there are separate certification data for these categories[8]. All CH_4 and N_2O data were binned by 2-stroke and 4-stroke nonroad motorcycles and ATVs. A comparison of current and proposed emission factors for motorcycles and ATVs is shown in Table 5.

TABLE 5. MOTORCYCLE AND ATV EMISSION FACTORS FROM CERTIFICATION DATA

Vehicle	g/mile			
	CH_4		N_2O	
	Current	Proposed	Current	Proposed
2-stroke off-highway motorcycle	0.772	0.175	0.007	0.013
4-stroke off-highway motorcycle	0.306	0.128	0.007	0.013
2-stroke ATV	0.392	1.512	0.007	0.077
4-stroke ATV	0.244	0.141	0.007	0.077

Certification data are also used to update emission factors for gasoline-[9] and distillate fuel-[10]powered engines used in recreational and commercial marine applications (Table 6).

[6] https://www.epa.gov/sites/production/files/2020-01/large-spark-ignition-2011-present.xlsx

[7] https://www.epa.gov/sites/production/files/2020-01/nonroad-compression-ignition-2011-present.xlsx

[8] https://www.epa.gov/sites/production/files/2020-01/off-road-mc-atv-utv-recveh-2006-present.xlsx

[9] https://www.epa.gov/sites/production/files/2020-01/marine-spark-ignition-2011-present.xlsx

[10] https://www.epa.gov/sites/production/files/2020-01/marine-compression-ignition-2000-present.xlsx

TABLE 6. MARINE EMISSION FACTORS FROM CERTIFICATION DATA

Vessel Type/Fuel	g/kWh			
	CH_4		N_2O	
	Current	Proposed	Current	Proposed
2-stroke Outboard	0.772	0.175	0.007	0.013
2-stroke Personal Water Craft	0.306	0.128	0.007	0.013
4-stroke Inboard/Sterndrive	0.392	1.512	0.007	0.077
Distillate	0.023	0.450	0.035	0.012

It should be noted that starting in 2015, all ocean-going vessels operating within 200 nautical miles of the U.S. coastline must use fuel containing no more than 0.1% sulfur. In most cases, vessels are using distillate fuel while operating within this Emissions Control Area. Steamships are exempt from that requirement until 2020. Therefore, the current method of using residual fuel sales to determine residual fuel use for domestic cargo movements needs to be reviewed.

Calculation of Emission Factors (g/kg fuel)

Using the emission factors in terms of g/kWh from Table 4, emissions of CH_4 and N_2O were calculated by SCC and horsepower bin. MOVES was used to determine average horsepower, load factor, and hours for each SCC and horsepower bin and then combined by source category and fuel type listed in Table 1. Fuel consumption from MOVES was also summed for the same categories and fuels. Emission factors in units of grams per kg of fuel are then determined by dividing the total CH_4 and N_2O emissions, respectively, by fuel consumption. New emission factors in terms of grams per kg of fuel consumed are provided in Table 7, by source category and fuel type, and compared with the emission factors currently used in the Inventory.

TABLE 7: CALCULATED AND PROPOSED EMISSION FACTORS FOR 2019

Vehicle / Fuel Type	grams per kg fuel			
	CH_4		N_2O	
	Current	Proposed	Current	Proposed
Ships and Boats				
Gasoline 2-stroke	3.41	1.64	0.02	0.03
Gasoline 4-stroke	1.66	0.80	0.08	0.00
Diesel	0.10	2.01	0.16	0.05
Farm Equipment				
Gasoline 2-stroke	4.65	2.48	0.02	0.17
Gasoline 4-stroke	2.48	0.69	0.08	0.43
Diesel	0.08	0.40	0.15	0.34
CNG	11.82	1.74	0.20	0.08
LPG	1.01	0.16	0.19	0.46
Construction & Mining Equipment				

Gasoline 2-stroke	4.45	2.86	0.03	0.04
Gasoline 4-stroke	1.98	1.02	0.07	0.53
Diesel	0.06	0.32	0.15	0.29

Vehicle / Fuel Type	grams per kg fuel			
	CH_4		N_2O	
	Current	Proposed	Current	Proposed
CNG	67.69	1.57	0.19	0.44
LPG	0.44	0.29	0.20	0.24
Lawn and Garden Equipment				
Gasoline 2-stroke-Residential	5.91	2.38	0.02	0.17
Gasoline 4-stroke-Residential	2.20	1.08	0.06	0.70
Gasoline 2-stroke-Commercial	5.58	2.61	0.02	0.11
Gasoline 4-stroke-Commercial	2.08	1.07	0.07	0.53
Diesel-Commercial	0.10	0.21	0.15	0.15
LPG-Commercial	0.15	0.20	0.20	0.31
Airport Equipment				
Gasoline 4-stroke	0.92	0.37	0.09	0.38
Diesel	0.05	0.59	0.15	0.36
LPG	0.15	0.17	0.20	0.43
Industrial & Commercial Equipment				
Gasoline 2-stroke	5.42	2.60	0.02	0.18
Gasoline 4-stroke	1.94	0.98	0.07	0.55
Diesel	0.06	0.13	0.15	0.19
CNG	14.92	2.89	0.20	0.04
LPG	0.19	0.22	0.20	0.31
Logging Equipment				
Gasoline 2-stroke	4.31	3.47	0.03	0.00
Gasoline 4-stroke	2.32	1.16	0.07	0.73
Diesel	0.02	0.15	0.15	0.40
Railroad Equipment				
Gasoline 4-stroke	2.04	1.16	0.07	0.65
Diesel	0.13	0.12	0.13	0.30
LPG	0.48	0.97	0.20	0.00
Recreational Equipment				
Gasoline 2-stroke	2.69	2.21	0.01	0.06
Gasoline 4-stroke	2.98	1.59	0.08	0.84
Diesel	0.13	0.23	0.13	0.21
LPG	1.36	0.21	0.18	0.29
Off-Road Trucks				
Diesel	0.03	0.29	0.16	0.17

Finally, overall emissions of methane and nitrous oxide for calendar year 2019 using the current and proposed methodologies are compared in Table 8.

Table 8. Total CH_4 and N_2O emissions for 2019

Fuel	Metric Tons			
	CH_4		N_2O	
	Current	Proposed	Current	Proposed
Gasoline 2-stroke	17,732	9,731	100	263
Gasoline 4-stroke	28,492	14,371	958	7,325
Diesel	2,802	14,486	6,427	11,730
CNG	14,016	2,697	191	42
LPG	963	1,101	1,026	1,578
Total	64,006	42,386	8,701	20,938

As can be seen from Table 8, total CH_4 emissions are lower using the new emission factors while N_2O is more than double.

To get an idea of how the proposed update impacts the total nonroad inventory, CO_2 emissions are estimated from MOVES and combined with global warming factors to calculate CO_2e. CO_2 emissions byfuel type are shown in Table 9, global warming factors in Table 10, and total nonroad greenhouse gas emissions are in Table 11.

Table 9. Estimated CO_2 emissions

Fuel	Fuel MT	CO_2/Fuel Ratio	CO_2 MT
Gasoline 2-stroke	4,909,093	3.035	14,900,146
Gasoline 4-stroke	13,676,181	3.035	41,510,127
Diesel	43,105,890	3.194	137,665,845
CNG	945,705	2.655	2,510,532
LPG	5,083,656	2.999	15,247,578
Total	67,720,525		211,834,228

Table 10. Global Warming Potential Factors

Specie	GWP
CO_2	1
CH_4	25
N_2O	298

Table 11. Total GHG Emission Comparisons

Fuel	CO2e (MT)		Difference
	Current	Proposed	
Gasoline 2-stroke	15,373,256	15,221,740	-1.0%

Fuel	CO2e (MT)		Difference
	Current	Proposed	
Gasoline 4-stroke	42,507,776	44,052,223	3.6%
Diesel	139,651,141	141,523,616	1.3%
CNG	2,917,747	2,590,338	-11.2%
LPG	15,577,445	15,745,404	1.1%
Total	216,027,365	219,133,320	1.4%

Onroad Motorcycles

The current methodology for calculating methane and nitrous oxide emissions from onroad motorcyclesrelies on emission factors that were developed in 2004[11]. Limited data existed at the time for methane and nitrous oxide emissions from onroad motorcycles, so emission factors were estimated from light- duty passenger cars of the same emission control strategy, using the ratio of CO_2 emissions. Since that time, emission standards have been established for motorcycles, requiring more advanced aftertreatment technology. Emissions from these motorcycles are now captured in the certification datacompiled by EPA[12]. Updated CH_4 and N_2O emission factors for motorcycles are derived from EPA certification data.

Calculation of Emission Factors

Updated emission factors are calculated using certification data available for model year 2006 and newer onroad motorcycles. The term “advanced” is used below to describe these newer motorcycles which have improved emissions controls. Current and proposed emission factors for CH_4 and N_2O are shown in Table 12. Model years corresponding to each emission control technology category are shown in Table 13.

TABLE 12. ONROAD MOTORCYCLE EMISSION FACTORS

Emission Control Technology	Grams per mile			
	CH4		N2O	
	Current	Proposed	Current	Proposed
Uncontrolled	0.090	0.090	0.009	0.009
Non-catalyst	0.067	0.067	0.007	0.007
Advanced	0.067	0.066	0.007	0.018

[11] Browning, L. Update of Methane and Nitrous Oxide Emission Factors for On-Highway Vehicles. Prepared for the U.S. EPA by ICF Consulting, February 17, 2004.

[12] https://www.epa.gov/sites/production/files/2020-01/on-hwymc-2006-present.xlsx

TABLE 13. ONROAD MOTORCYCLE CONTROL TECHNOLOGY BY MODEL YEAR

Emission Control Technology	Affected Model Years
Uncontrolled	Before 1996
Non-catalyst	1996-2005
Advanced	2006 and later

To assess the impact of the proposed emission factors on calculated CH_4 and N_2O emissions from onroadmotorcycles, mileage accumulation data from 2018 was used to calculate total methane and nitrous oxide emissions using both the current and proposed emission factors (Table 14). The proposed emission factors result in lower methane emissions and higher nitrous oxide emissions from onroad motorcycles.

TABLE 14. COMPARISON OF CH_4 AND N_2O EMISSIONS FROM ONROAD MOTORCYCLES USING THE CURRENT AND PROPOSED METHODOLOGIES

Emission Control Technology	VMT 10^9	Metric Tons			
		CH_4		N_2O	
		Current	Proposed	Current	Proposed
Uncontrolled	0.28	24.77	24.77	2.41	2.41
Non-catalyst	2.23	149.70	149.70	15.26	15.26
Advanced	4.22	283.84	279.34	28.93	75.54
Totals	6.73	458.30	453.80	46.60	93.21

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2019:

Updated Gasoline and Diesel Fuel CO_2 Emission Factors

This memo provides research and analyses to support improvements in the U.S. Greenhouse Gas Inventory. Updated gasoline and diesel fuel carbon factors in terms of amount of carbon per energy content of fuel are estimated.

Summary

This memo details suggested changes to the gasoline and diesel fuel carbon factors used in the U.S. Greenhouse Gas Inventory.

- **Current Method –** The current inventory lists NIPER (1990 through 2009) data[1] to determine gasoline composition. NIPER has ceased to exist and the referenced reportsare out of circulation. The current C share for distillate is drawn from Perry's Chemical Engineers' Handbook, 8th Ed. (Green & Perry 2008). Current C factors have not been updated since 2010 (for the 1990-2008 Inventory Report).

- **Proposed Method –** Fuel data available from the North American Fuel Survey (NAFS[2]) were used to calculate the carbon mass fraction for gasoline and the carbon mass fraction, API gravity and heating values for diesel fuel from 2000 to 2018. It is proposed to use these data to develop gasoline and diesel carbon factors for these years. For diesel fuel it is proposed to use an average of years 2000 to 2005 to update factors from1990 to 1999. For gasoline it is proposed to use the current Inventory values based on NIPER for years 1990 to 1999.

- **Charge Questions –** There are charge questions related to the proposed methods provided at the end of the memo to help focus the review

Background

The current GHG inventory calculates grams of carbon dioxide (CO_2) emitted from gasoline and diesel fuel consumption based upon the gallons of fuel used. A conversion factor is used to convert gallons into quadrillion Btus (QBtu) and another factor is used to compute CO_2 emissions from energy use. This latter factor provides million metric tonnes (MMT) of carbon (C)per QBtu of fuel and is based upon the density, higher heating value and carbon content (mass fraction) of the fuel. Once the amount of carbon is calculated, the amount of CO_2 generated can be estimated by the ratio of the molecular weights of CO_2 and carbon.

[1] National Institute for Petroleum and Energy Research (NIPER) (1990 through 2009) Motor Gasolines, Summer and MotorGasolines, Winter.

[2] Alliance of Automobile Manufacturers Winter (January) and Summer (July) North American Fuel Surveys (NAFS), https://autoalliance.org/energy-environment/fuel-publications/

The National Institute for Petroleum and Energy Research (NIPER) compiled properties of summer and winter gasolines from 1990 to 2009[1]. These were used to determine the component composition of different gasolines. The NIPER data along with assumed C contents of the different components were

used to compute the carbon fraction assumed in the Inventory.The C share for distillate was drawn from Perry's Chemical Engineers' Handbook, 8th Ed.

Carbon share was combined with heat contents for distillates and densities to calculate C coefficients for each distillate type. Since that time the carbon factor has not been updated toreflect current fuel properties.

The proposed approach described here relies on fuel properties gathered through the Alliance of North American Fuel Survey (NAFS) published by the Alliance of Automobile Manufacturers (AAM), an association which is now part of the Alliance for Automotive Innovation. This fuel survey is conducted twice per year, in January and July, and includes measured properties of both regular and premium gasoline as well as diesel fuel. While the exact number of samples vary by year and location, fuel samples are drawn from multiple retail locations in each of over 20 U.S. cities for each biannual survey. The Energy Information Administration (EIA) publishes prime supplier sales volumes of motor gasoline by type (conventional, oxygenated, and reformulated) and by grade (regular, midgrade and premium) as well as for diesel fuel for each month from 1983 to present.[3] Combing these two sources allows for the determination of annualC content of gasoline and diesel fuel over the time series of the Inventory.

Typically, the C content of hydrocarbon fuel is calculated according to ASTM D3343, *StandardTest Method for the Estimation of Hydrogen Content of Aviation Fuels;* the method applies to hydrocarbon containing fuels only and is not applicable towards oxygenated fuel blends.
However, recently EPA has proposed an amendment to 40 CFR §600.113-12, containingequations allowing for the estimation of base fuel blendstock properties using the bulk oxygenated fuel properties.[4] This technique is applied here for oxygenated gasoline calculations.

Assumptions

The fuels sampled in the NAFS by AAM are assumed to be representative of the seasonal fuelssold throughout the U.S. Also, the method of calculation of the fuel properties of the hydrocarbon fraction of the fuel from blended fuel properties was developed for Tier 3 certification test fuels, and not commercial fuel blends as used here.

[3] EIA, *Prime Supplier Sales Volume* at https://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm
[4] Notice of Proposed Rulemaking. *Vehicle Test Procedure Adjustments for Tier 3 Certification Test Fuel*, EPA-HQ-OAR-2016- 0604. https://www.federalregister.gov/documents/2020/05/13/2020-07202/vehicle-test-procedure-adjustments-for-tier-3- certification-test-fuel

The two ASTM standard methods used for the calculation of carbon content and other properties, ASTM D3343 and D3338, were developed specifically for aviation fuels and not motor vehicle fuels. However, the EPA and other organizations regularly uses these methodsfor both gasoline and diesel fuel, and both are specified methods in Code of Federal Regulations (CFR) fuel economy calculations.

Calculations

Using the monthly sales of gasoline from EIA, annual totals of conventional, oxygenated and reformulated gasoline is determined for both summer and winter. Gasoline sold in May – Aug was assumed to be summer grade, gasoline sold in September was assumed to be half summer and half winter grade, and gasoline sold in other months was assumed to be winter grade. The amount of ethanol within each gasoline is removed as ethanol is treated separatelyin the inventory. Total volumes of gasoline sales are shown in Table 1 and monthly sales data for diesel fuel are presented in Table 2.

Table 1. Non-Ethanol Gasoline Sales in Millions of Gallons

Calendar	Regular		Midgrade		Premium	
Year	Winter	Summer	Winter	Summer	Winter	Summer
1990	48,924	31,312	6,968	4,727	14,640	10,134
1991	50,238	32,136	7,420	4,805	13,508	8,615
1992	50,210	31,362	8,564	5,360	14,349	8,819
1993	48,674	30,695	8,601	5,407	14,348	9,127
1994	49,716	31,585	8,842	5,595	15,002	9,412
1995	50,055	32,660	9,550	6,035	15,089	9,193
1996	52,914	34,403	9,498	5,743	13,631	8,047
1997	55,056	34,920	9,040	5,753	12,688	8,174
1998	55,690	35,654	8,907	5,589	13,972	8,886
1999	58,077	36,975	8,617	5,370	13,630	8,397
2000	60,757	39,362	7,423	4,589	10,757	6,640
2001	62,859	40,641	6,919	4,226	10,913	6,449
2002	64,452	41,290	6,844	4,313	11,151	7,114
2003	65,962	42,317	6,327	3,990	10,140	6,656
2004	68,269	43,434	5,904	3,473	9,503	5,683
2005	70,316	44,909	5,436	3,573	8,480	5,428
2006	71,485	45,460	4,915	2,921	8,118	4,928
2007	71,717	45,351	4,575	2,828	7,943	5,058
2008	71,152	43,783	4,177	2,495	7,170	4,070
2009	69,932	44,349	3,720	2,378	7,337	4,706

2010	70,379	44,830	3,459	2,248	7,448	4,951
2011	69,506	43,424	3,080	1,923	7,120	4,504
2012	67,898	42,455	2,976	1,965	7,110	4,683

Calendar	Regular		Midgrade		Premium	
Year	Winter	Summer	Winter	Summer	Winter	Summer
2013	68,143	42,610	2,325	1,772	7,539	4,872
2014	68,199	42,792	1,556	1,000	7,965	5,036
2015	70,287	44,330	1,553	1,023	8,870	5,721
2016	72,231	45,559	1,567	1,020	9,471	6,204
2017	72,709	46,144	1,477	988	9,356	6,244
2018	72,839	46,374	1,329	868	9,289	6,031

Table 2. Diesel Fuel Sales in Millions of Gallons

Calendar	Total Diesel Fuel	
Year	Winter	Summer
1990	30,988	17,774
1991	30,570	16,710
1992	31,514	16,714
1993	30,418	16,075
1994	30,891	16,848
1995	30,968	17,220
1996	32,825	17,869
1997	32,635	18,225
1998	32,617	18,805
1999	34,362	19,207
2000	34,577	20,278
2001	36,081	20,315
2002	34,422	19,950
2003	35,942	20,265
2004	36,561	20,686
2005	36,719	21,691
2006	37,589	22,303
2007	39,090	22,568
2008	37,213	21,567
2009	33,817	19,435
2010	35,131	20,877
2011	35,514	20,751

2012	34,588	20,853
2013	35,529	20,805
2014	37,217	22,067
2015	37,469	22,137
2016	36,661	21,713
2017	38,168	23,465
2018	40,109	24,025

The carbon content and net heating value (NHV)[5] of diesel fuel is calculated according to ASTMD3343[6], *Standard Test Method for the Estimation of Hydrogen Content of Aviation Fuels,* and ASTM D3338[7], *Standard Test Method for the Net Heat of Combustion of Aviation Fuels,* respectively using fuel properties inputs from the NAFS for each year and season. These methods use a correlation between the measured fuel distillation range, API gravity, and aromatic content to estimate the hydrogen content[8] and net heating values by Equations 1 through 3 below; N_1 through N_{10} represent the resulting coefficients from the regression analysisperformed by ASTM.

$$\%H = N_1(G) - N_2(A) + N_3(AV) + N_4(GV) - N_5(GA) + 10.56$$

Eq. 1

$$Q_{p1} = N_6(G) - N_7(A) + N_8(GV) - N_9(AG) + N_{10}(AGV) + 17685$$

Eq. 2

where %H = mass percent hydrogen
G = gravity, °API
A = volume percent aromatics
V = average of 10%, 50%, and 90% distillation data, °F, asmeasured using ASTM D86
Q_{p1} = net heat of combustion, BTU/lb, sulfur-free basis

To correct for the effect of sulfur content of the fuel on the net heat of combustion, Equation 3 is applied as follows.

$$Q = Q_{p1} \times [1 - 0.01(S)] + 43.7(S) \qquad \textit{Eq. 3}$$

[5] Gross (or high) heating value (GHV) is needed for the calculations in the Inventory as the data on fuel use is provided in terms of gross heating value. NHV is converted to GHV by assuming NHV = 0.95*GHV for petroleumfuels.
[6] ASTM International, ASTM D3343-16, *Standard Test Method for Estimation of Hydrogen Content of Aviation Fuels,* https://www.astm.org/Standards/D3343.htm
[7] ASTM International, ASTM D3338M-20, *Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels*,https://www.astm.org/Standards/D3338.htm
[8] As equations are based on assuming hydrocarbon containing fuels only, C % is 100 - H %.

where Q = net heat of combustion, BTU/lb, of the fuel containing Sweight percent sulfur

S = mass percent sulfur

The carbon mass fraction of the hydrocarbon fraction of gasoline, CMF_{HC}, is calculated according to ASTM D3343, using the following corrected inputs as described in the Vehicle TestProcedure Adjustments for Tier 3 Certification Test Fuel amendments to 40 CFR §600.113-12.[9]

$$A_{HC} = \frac{VP_{aro,f}}{1 - VF_e} \qquad \textit{Eq. 4}$$

$$_{HC}\ \frac{G}{SG_{HC}} = {}^{141.5} - 131.5 \qquad \textit{Eq. 5}$$

$$SG_{HC} = \frac{SG_f - SG_e \cdot VF_e}{1 - VF_e} \qquad \textit{Eq. 6}$$

$$V_{HC} = V + 14.8 \qquad \textit{Eq. 7}$$

where A_{HC} = volume percent aromatics of the hydrocarbon fraction $VP_{aro,f}$ = volume percent aromatics of the blended fuel

VF_e = volume fraction ethanol of the blended fuel G_{HC} = gravity, °API, of the hydrocarbon fraction SG_{HC} = specific gravity of the hydrocarbon fraction SG_f = specific gravity of the blended fuel

SG_e = 0.7939, specific gravity of ethanol,

V_{HC} = average of 10%, 50%, and 90% distillation data, °F, of the hydrocarbon fraction

[9] Notice of Proposed Rulemaking. *Vehicle Test Procedure Adjustments for Tier 3 Certification Test Fuel*, EPA-HQ-OAR-2016-0604. https://www.federalregister.gov/documents/2020/05/13/2020-07202/vehicle-test-procedure-adjustments-for-tier-3-certification-test-fuel

The fuel carbon content for gasoline and diesel fuel and the NHV for diesel were determined separately for each city and season included for each year in the NAFS. For gasoline, these values were averaged by fuel PADD (Petroleum Administration for Defense Districts) to assure accurate representations for each distribution area. To determine annual national values for gasoline carbon content, a weighted average was performed using the sales volumes for each season and PADD as published by the U.S. Energy Information Administration (EIA). For dieselnational fuel averages for summer and winter were combined with sales volumes for each season to determine a national total.

Table 3. Annual carbon fraction of diesel for Winter and Summer NAFS samples.

Year	Annual Carbon Content of Diesel	
	Winter Diesel	Summer Diesel
2000		0.8706
2001	0.8700	0.8700
2002	0.8695	0.8703
2003	0.8698	0.8703
2004	0.8704	0.8707
2005	0.8702	0.8701
2006	0.8707	0.8683
2007	0.8681	0.8676
2008	0.8681	0.8676
2009	0.8674	0.8672
2010	0.8674	0.8675
2011	0.8672	0.8673
2012	0.8674	0.8672
2013	0.8676	0.8671
2014	0.8676	0.8671
2015	0.8674	0.8671
2016	0.8672	0.8669
2017	0.8671	0.8668
2018		0.8673

Table 4. Annual carbon fraction of gasoline determined by PADD-sales weighted averages for each season and grade.

Year	Annual Carbon Content of Gasoline			
	Winter Regular	Winter Premium	Summer Regular	Summer Premium
2000			0.8676	0.8692
2001	0.8538	0.8666	0.8671	0.8686
2002	0.8585	0.8664	0.8664	0.8622
2003	0.8762	0.8771	0.8693	0.8688
2004	0.8660	0.8675	0.8758	0.8683
2005	0.8659	0.8670	0.8644	0.8688
2006	0.8703	0.8698	0.8794	0.8710
2007	0.8739	0.8708	0.8767	0.8719
2008	0.8665	0.8704	0.8717	0.8710
2009	0.8710	0.8722	0.8723	0.8716
2010	0.8705	0.8713	0.8706	0.8701
2011	0.8713	0.8703	0.8726	0.8726
2012	0.8727	0.8726	0.8713	0.8706
2013	0.8702	0.8709	0.8710	0.8705
2014	0.8705	0.8699	0.8709	0.8702
2015	0.8695	0.8703	0.8711	0.8705
2016	0.8700	0.8717	0.8715	0.8713
2017	0.8715	0.8708	0.8712	0.8696
2018	0.8710	0.8698	0.8709	0.8694

The measured API gravity and the heating value calculated from ASTM D3338 for diesel fuel was used to determine the C content per energy unit. This method cannot be used easily for gasoline as it is an oxygenated blend, so the yearly heating value as published by EIA and previously reported API gravities are used for this purpose. Also, for gasoline, midgrade C content was assumed to be an average of Regular and Premium.

Table 5: Determination of C factor per mmBtu for diesel fuel

	C MF (kg C / kg)		Density (kg / gal)		GHV (mmBtu / gal)		kg C / mmBtu			
Year	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Average	Current
2000	0.8706		3.2360	0.0000	0.1382	0.0000	20.39		20.39	20.17
2001	0.8700	0.8700	3.2255	3.2163	0.1378	0.1374	20.36	20.36	20.36	20.17
2002	0.8703	0.8695	3.2318	3.2144	0.1380	0.1374	20.38	20.34	20.36	20.17
2003	0.8703	0.8698	3.2314	3.2222	0.1380	0.1377	20.38	20.36	20.37	20.17
2004	0.8707	0.8704	3.2421	3.2272	0.1384	0.1378	20.40	20.39	20.39	20.17
2005	0.8701	0.8702	3.2385	3.2282	0.1383	0.1379	20.37	20.38	20.37	20.17
2006	0.8683	0.8707	3.2011	3.2343	0.1371	0.1381	20.27	20.39	20.33	20.17
2007	0.8676	0.8681	3.2025	3.2032	0.1373	0.1373	20.24	20.26	20.25	20.17
2008	0.8676	0.8681	3.2062	3.2032	0.1374	0.1372	20.24	20.27	20.25	20.17
2009	0.8672	0.8674	3.2021	3.1994	0.1373	0.1372	20.22	20.23	20.23	20.17
2010	0.8675	0.8674	3.2043	3.2013	0.1374	0.1372	20.24	20.24	20.24	20.17
2011	0.8673	0.8672	3.2017	3.2002	0.1373	0.1372	20.23	20.22	20.22	20.17
2012	0.8672	0.8674	3.1990	3.1994	0.1372	0.1372	20.22	20.23	20.22	20.17
2013	0.8671	0.8676	3.1939	3.1954	0.1370	0.1370	20.21	20.24	20.23	20.17
2014	0.8671	0.8676	3.1919	3.1976	0.1369	0.1371	20.22	20.24	20.23	20.17
2015	0.8671	0.8674	3.1920	3.1949	0.1369	0.1370	20.21	20.23	20.22	20.17
2016	0.8669	0.8672	3.1934	3.1930	0.1370	0.1369	20.21	20.22	20.21	20.17
2017	0.8668	0.8671	3.1900	3.1930	0.1369	0.1370	20.20	20.21	20.20	20.17
2018	0.8673		3.1981	0.0000	0.1372	0.0000	20.22		20.22	20.17

Figure 1 shows the proposed calculated diesel fuel C emission factors compared to the current value. As noted earlier it is proposed to apply the 2000-2005 average to represent prior year values. It is assumed that the 200-2005 average is a good representation of diesel fuel used in prior years in terms of sulfur content.

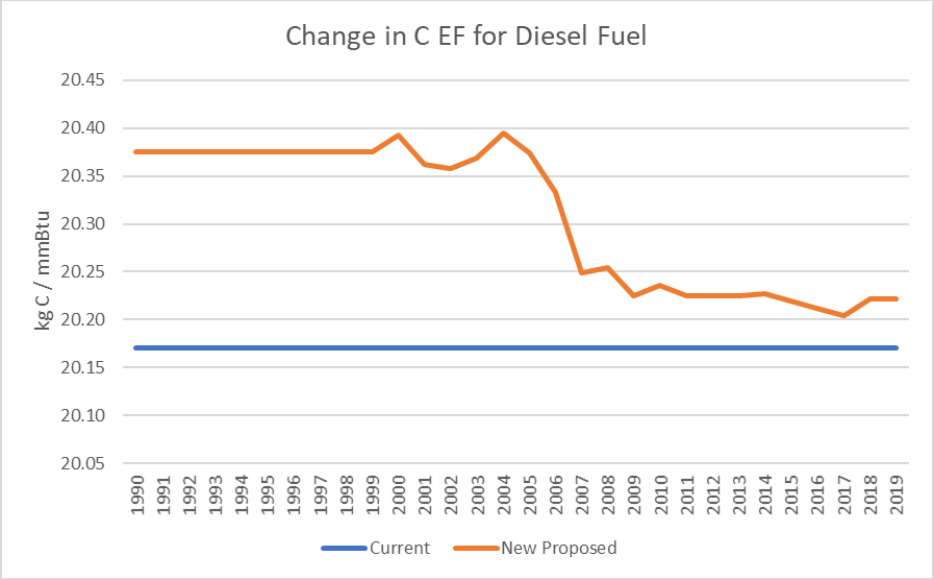


Figure 1: Diesel Fuel Proposed C Emission Factor

Table 6: Determination of C factor per mmBtu for gasoline

	PADD Sales Weighted C MF (kg C / kg)						kg C / mmBtu	
Year	Winter Reg	Winter Premium	Summer Reg	Summer Premium	Density (kg/gal)	HHV mmBtu/bbl	Average	Current
2000			0.8676	0.8692	2.79	5.22	19.47	19.33
2001	0.8538	0.8666	0.8671	0.8686	2.80	5.22	19.34	19.34
2002	0.8585	0.8664	0.8664	0.8622	2.79	5.22	19.36	19.38
2003	0.8762	0.8771	0.8693	0.8688	2.80	5.23	19.61	19.36
2004	0.8660	0.8675	0.8758	0.8683	2.79	5.24	19.43	19.38
2005	0.8659	0.8670	0.8644	0.8688	2.78	5.24	19.32	19.36
2006	0.8703	0.8698	0.8794	0.8710	2.79	5.25	19.47	19.45
2007	0.8739	0.8708	0.8767	0.8719	2.78	5.22	19.57	19.56
2008	0.8665	0.8704	0.8717	0.8710	2.77	5.22	19.35	19.46
2009	0.8710	0.8722	0.8723	0.8716	2.77	5.22	19.44	19.46
2010	0.8705	0.8713	0.8706	0.8701	2.77	5.22	19.39	19.46
2011	0.8713	0.8703	0.8726	0.8726	2.76	5.22	19.38	19.46
2012	0.8727	0.8726	0.8713	0.8706	2.76	5.22	19.35	19.46
2013	0.8702	0.8709	0.8710	0.8705	2.75	5.22	19.28	19.46
2014	0.8705	0.8699	0.8709	0.8702	2.75	5.22	19.26	19.46
2015	0.8695	0.8703	0.8711	0.8705	2.75	5.22	19.25	19.46
2016	0.8700	0.8717	0.8715	0.8713	2.75	5.22	19.27	19.46
2017	0.8715	0.8708	0.8712	0.8696	2.75	5.22	19.28	19.46

2018	0.8710	0.8698	0.8709	0.8694	2.75	5.22	19.27	19.46

Figure 2 shows the proposed calculated gasoline C emission factors compared to the current value. As noted earlier it is proposed to apply the current 1990-1999 values for prior years where new data is not available. The current values line up well with the new proposed data, soit is assumed the current values for prior years are still accurate.

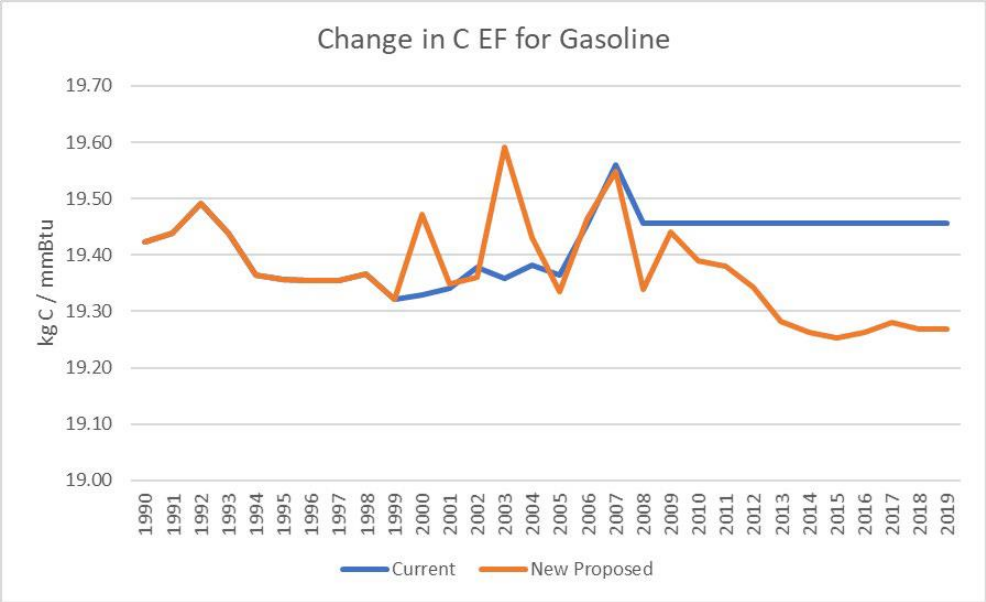


Figure 2: Gasoline Proposed C Emission Factors

The proposed diesel fuel emission factor update would result in minor increases in emissions over the time series. For years 1990-2005 the average annual increase in total emissions wouldbe 5.5 MMT CO_2 (~0.1% of emissions). For the years 2006-2018 the average annual increase in total emissions would be 2.1 MMT CO_2 (~0.04% of emissions). The proposed gasoline emission factor update would result in minor increases in emissions early in the time series and then decreases in emissions in more recent years. For years 1990-2005 the average annual increase in total emissions would be 1.5 MMT CO_2 (~0.03% of emissions). For the years 2006- 2018 the average annual decrease in total emissions would be 6.8 MMT CO_2 (~0.13% of emissions). The combined effect of both the proposed diesel fuel and gasoline emission factor update would be an increase in emissions early in the time series and then decreases in emissions in more recent years. For years 1990-2005 the average annual increase in total emissions would be 6.9 MMT CO_2 (~0.13% of emissions). For the years 2006-2018 the averageannual decrease in total emissions would be 4.7 MMT CO_2 (~0.09% of emissions).

Charge Questions

Calculation of Carbon Content:

1. The method used indicates that it applies to hydrocarbon containing fuels only and is notapplicable towards oxygenated fuel blends. However, EPA has developed methods to apply adjustments for oxygenated gasoline. Is the approach to apply these methods to gasoline appropriate?
2. This method has relied on fuel properties measured and published by AAM through theNorth American Fuel Survey. Do you agree with this source? Do you know of a better source for commercial gasoline and diesel fuel properties?
3. As fuel survey data is not available prior to the year 2000, this method has proposed using an average of the carbon content value from 2000-2005 for the years 1990-1999 for diesel fuel. For gasoline, this method has proposed maintaining the NIPER calculatedvalues for 1990-1999. Do you agree with this method?
4. Should the new proposed factors for diesel fuel be applied to only diesel fuel used in thetransportation sector or all diesel fuel used nationally?

Heating Value:

1. This proposed method uses measured API gravity and ASTM D3338 to calculate the heating value of diesel fuel to convert from carbon fraction by mass of fuel to carbon content by energy units (kg C/mmBtu). The previous approach used an assumed heating value of 5.809 MMBtu/bbl and assumed API gravity of 35.8 in the calculations. Do you agree that the proposed approach is an improvement or would there be a betterapproach?
2. Similarly, the estimation of base fuel property calculations for oxygenated gasolinefollowing the proposed Tier 3 certification test fuel calculations could be used to approximate the heating value for the gasoline base fuel. Should this be done for consistency? If not, is there a better approach?
3. EPA is considering using the heating value calculated from ASTM D3338 and fuel properties from NAFS to update the gasoline and diesel fuel heating values in other places of the inventory, replacing the values published by EIA in future inventories. Doyou agree that this would be an appropriate improvement? Do you know of a better approach?

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2019:
Waste Incineration Data Analysis Proposed Improvements

1. Introduction

EPA has researched and is proposing potential improvements to the Incineration of Waste source category of the U.S. Greenhouse Gas (GHG) Inventory by identifying more recent and relevant data sources for total wastegenerated and incinerated. EPA conducted analyses during the 1990-2019 Inventory cycle to compare these data sources. This memorandum outlines these proposed improvements, data sources, and required analysis.

2. Proposed Improvements

Proposed improvements for this year's Waste Incineration estimates will focus on two specific areas:

(1) implementation of new data sources for municipal solid waste (MSW) combusted values (i.e., tonnage)for estimating CO_2 and non-CO_2 (i.e., CH_4, N_2O) emissions, and
(2) updating the methodology by which CO_2 estimates are calculated by using a carbon content per ton ofwaste incinerated factor (e.g., MMT CO_2 per ton of waste incinerated).

2.1 Current Inventory Approach

Currently in the Inventory, data on waste disposed (excluding tires) and waste incinerated from BioCycle's *Stateof Garbage in America* (van Haaren et al. 2010) (hereinafter referred to as BioCycle data) and Shin (2014) are used for years 1990 through 2011, i.e., when the data were last updated. For timeseries estimates after 2011, data have been proxied using the 2011 disposal and incineration tonnages from Shin (2014).

CO_2 emissions from the incineration of waste are calculated by material separately for plastics, synthetic rubber,and synthetic fibers in MSW. Data on the quantity of product disposed are from *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures* (EPA 2000 - 2003, 2005 - 2014); *Advancing Sustainable Materials Management: Facts and Figures: Assessing Trends in Material Generation, Recycling and Disposal in the United States* (EPA 2015; EPA 2016; EPA 2018a; EPA 2019); and detailed unpublished backup data for some years not shown in the reports (Schneider 2007). Data on the percent of disposed material that gets incinerated is obtained from the BioCycle data.

The amount of incinerated material, obtained from the BioCycle data, is multiplied by its carbon content to calculate the total amount of carbon emitted. The carbon content of the product is based on the specific material properties. Information about scrap tire composition and amount combusted was obtained from theRubber Manufacturers' Association (RMA 2018).

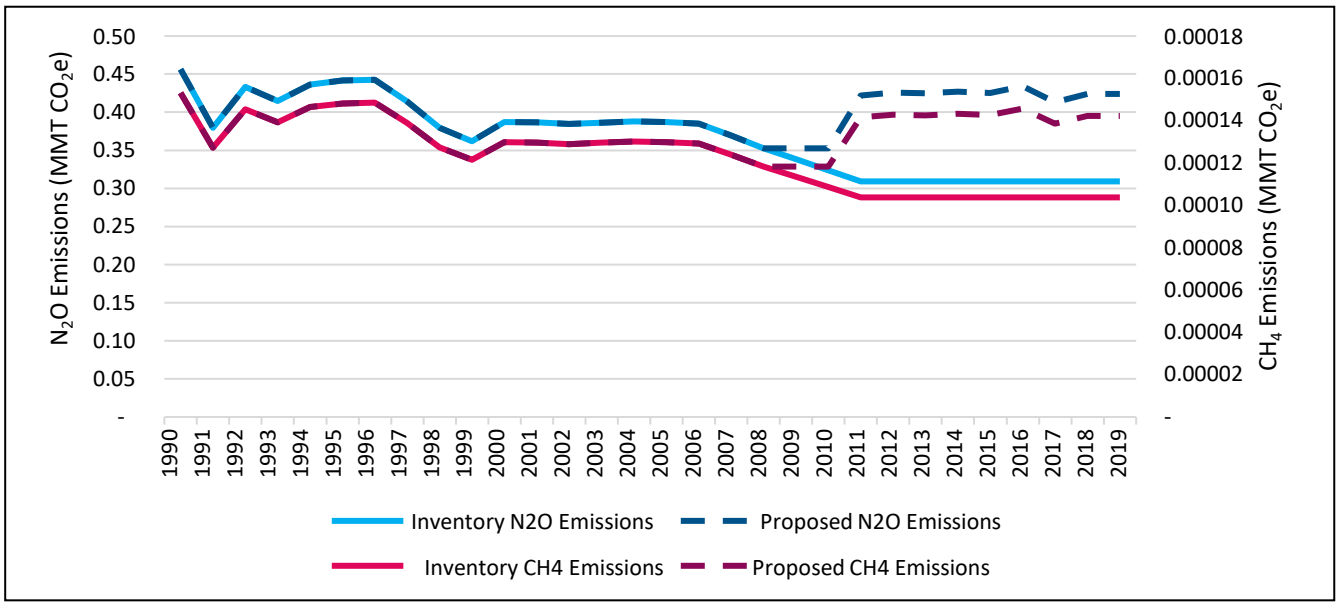
2.2 Use of GHGRP for Waste Disposed and Incinerated Data

EPA's *Greenhouse Gas Reporting Program* (GHGRP) collects data from facilities on total non-biogenic and biogenic CO_2 and non-CO_2 emissions from waste incineration, with data collected starting in 2010. From these emissions estimates, EPA can calculate the tonnage of waste incinerated using GHGRP emission factors for $CH_4$and N_2O[1].

[1] EPA is also investigating the effects of nonreporters on the RMA (2018), EPA would continue to calculate CO2 emissions fromincineration of tires separately using the current Inventory approach.

Starting in 2010 in the time series, EPA is proposing to utilize the tonnage of waste incinerated derived fromGHGRP data for MSW and tires to replace the proxied data from BioCycle, Shin (2014), and RMA (2018). EPAwould continue to apply the same emission factors for CH_4 and N_2O to develop the non-CO_2 emissions estimates. Figure 1 shows the effect of this proposed approach on N_2O and CH_4 emissions compared to the current Inventory estimates.

Figure 1. Proposed N_2O and CH_4 Emissions using BioCycle and GHGRP Data (including Tires) Compared to Current Inventory Estimates



2.3 Calculation of Carbon Content per Ton of Waste Incinerated

EPA is proposing to calculate CO_2 emissions from the incineration of waste by applying an emission factor basedon an aggregated carbon content per ton of waste incinerated. To obtain the aggregate carbon content for all waste incinerated (excluding tires), EPA applied an approach that uses discard and incineration rates of fossil MSW from EPA's *Advancing Sustainable Materials Management: Facts and Figures – Assessing Trends in Material Generation, Recycling and Disposal in the United States* report (EPA 2019).

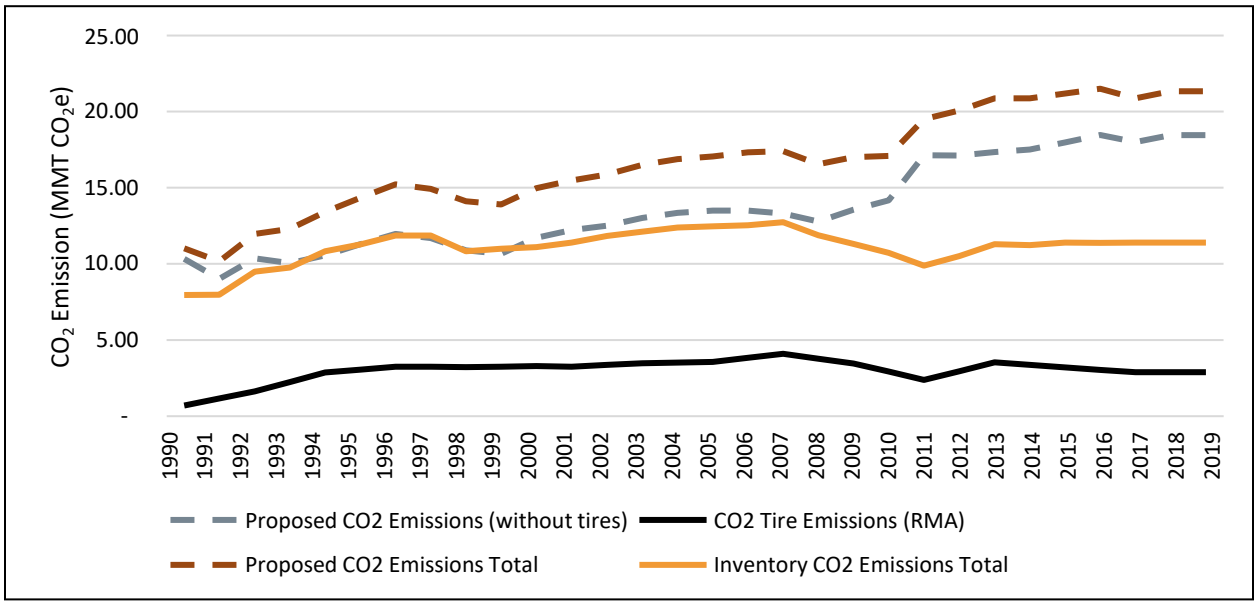
The fossil MSW categories in EPA (2019) include plastics, textiles, and other non-durable and durable goods. Using a combination of moisture content and carbon content for each category of waste, EPA estimated an annual carbon content for each material and calculated the overall carbon content for incinerated waste using aweighted average of carbon contents for each waste category. Table 1 shows the calculated carbon contents in kilograms of CO_2 per ton of waste incinerated. More detail on carbon content calculations are provided in Annex 1.

Table 1. Calculated Fossil Carbon Content per Ton of Waste Incinerated (kg CO_2/ton)

	1990	2005	2015	2016	2017	2018	2019
CO_2 Emission Factor	310	509	619	622	633	633	633

EPA applied the average annual fossil carbon content to the total waste incinerated (excluding tires) derived from BioCycle and GHGRP data used in the non-CO_2 emissions calculations. Figure 2 shows the comparison ofCO_2 emissions using an aggregate carbon content emission factor compared to emissions in the current Inventory.

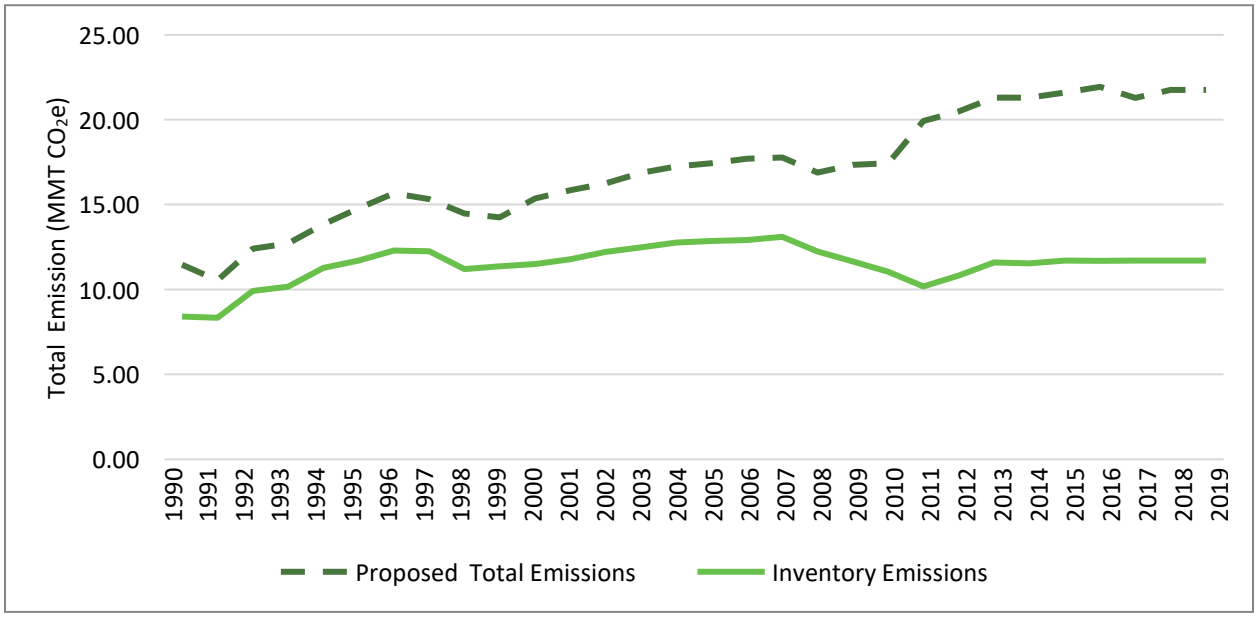
Figure 2. Proposed CO_2 Emissions (With and Without Tires) Compared to Current Inventory Estimates



3. Impacts of Proposed Improvements on Emissions Estimates

Overall, the proposed changes in data sources and methodology would lead to an increase in emissions by 49%across the time series from the Incineration of Waste source category (see Figure 3). The observed increase in emissions is primarily due to the difference in waste incineration mass flows reported in GHGRP and BioCycle over the last 10 years.

Figure 3. Proposed Total CO_2 and Non-CO_2 Emissions from Incineration of Waste Compared to Current Inventory Estimates



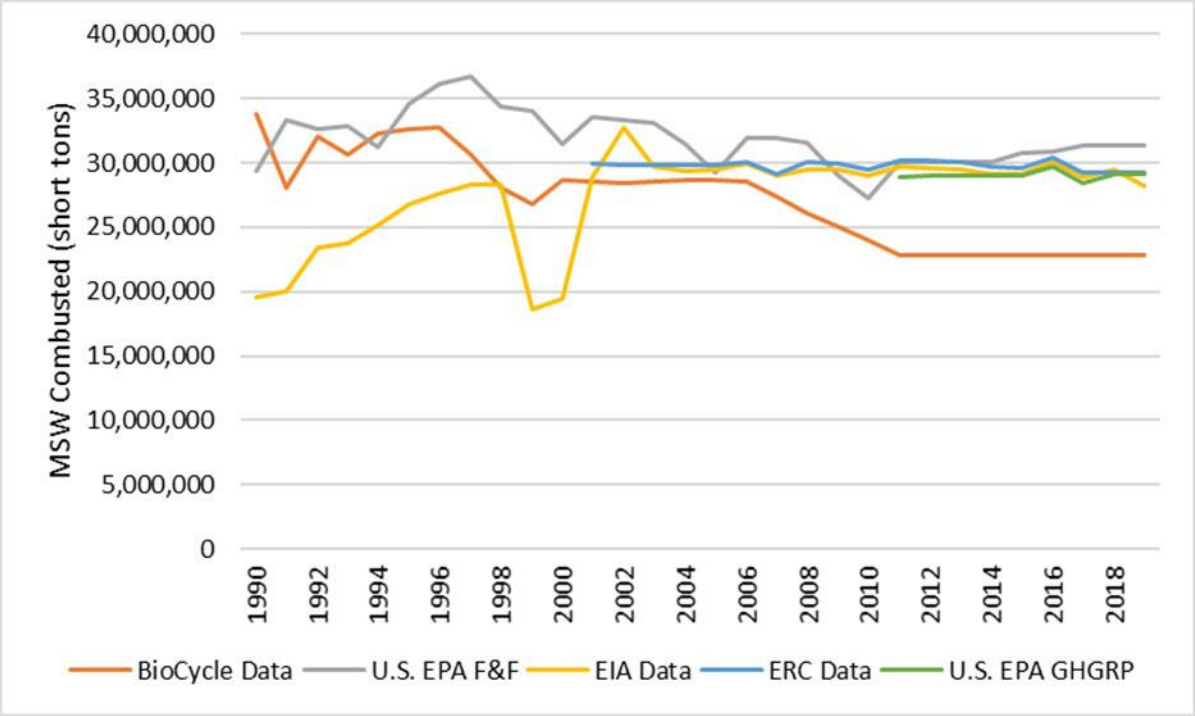
4. Charge Questions

EPA is requesting comment on the decision to use GHGRP data to derive tonnage of waste incinerated startingin 2010, i.e., when BioCycle data became unavailable. EPA examined several other data sources for waste incineration tonnages, including from:

- U.S. Energy Information Administration (EIA) and St. Louis Federal Reserve's Economic Data (FRED) (EIA2019),
- *Advancing Sustainable Materials Management: Facts and Figures Report* EPA (2019), and
- the Energy Recovery Council's *2018 Directory of Waste to Energy Facilities* (ERC 2018).

EPA reviewed each data source for quality, time series consistency, ease of access (particularly for future updates), and transparency in methods. After its review, EPA selected the GHGRP data due to the bottom-upapproach of accounting for waste incinerated by facility, data transparency, and ease of access for future updates. Figure 4 shows the comparison of MSW incinerated from different sources analyzed.

Figure 4. Comparison of MSW Combusted from Different Sources



EPA is also requesting comment on the approach to estimate CO_2 emissions using an aggregate carbon content for all waste incinerated (excluding tires). This includes the assumptions around carbon content per componentand assumed moisture content of waste as shown in Annex 1.

5. Annex 1: Carbon Content Calculations per Ton of MSW

The following assumptions went into the calculation:

- Data from the EPA Facts and Figures Reports represented the composition of MSW discarded and thatthe composition of waste incinerated was the same as the composition of waste discarded.
- The data collected on MSW incinerated from the different sources including Biocycle and EPA GHGRPwas based on wet tons of MSW.
- Fossil carbon content of individual waste components were based on the current Inventory assumptions, biogenic carbon contents and moisture contents were based on academic research (Staleyand Barlaz 2009, Barlaz 1998)

Table 2. Short Tons of Waste Discarded (Wet)

('000 short tons)	1990	2000	2010	2017
Paper and Paperboard	52,500	50,180	26,740	22,840
Glass	10,470	9,890	8,390	8,350
Ferrous Metals	10,410	9,470	11,120	12,720
Aluminum	1,800	2,330	2,830	3,210
Other Nonferrous Metals	370	540	580	790
Plastics	16,760	24,070	28,900	32,410
PET	*1,239*	*2,122*	*3,452*	*4,100*
HDPE	*2,935*	*4,542*	*4,926*	*5,570*
PVC	*1,397*	*1,432*	*919*	*960*
LDPE/LLDPE	*4,695*	*5,757*	*7,076*	*7,740*
PP	*2,590*	*3,440*	*7,540*	*7,950*
PS	*2,078*	*2,348*	*2,059*	*2,340*
Other	*1,826*	*4,429*	*2,927*	*3,750*
Rubber and Leather	5,420	5,850	6,310	7,440
Tires	*3,170*	*3,640*	*2,860*	*3,930*
Other (dur. & non-dur.)	*2,250*	*2,210*	*3,450*	*3,510*
Textiles	5,150	8,160	11,170	14,320
Wood	12,080	12,200	13,430	14,990
Other	2,510	3,020	3,340	3,650
Food Wastes	23,860	30,020	34,770	38,100
Yard Trimming	30,800	14,760	14,200	10,760
Miscellaneous Inorganic Wastes	2,900	3,500	3,840	4,040
Total MSW Discarded	175,030	173,990	165,620	173,620
Total Minus Tires	171,860	170,350	162,760	169,690

Note: 2017 is the latest year data is available for waste composition.

Table 3. Moisture Content of MSW Components

	1990	2000	2010	2017
Paper and Paperboard	6%	6%	6%	6%
Glass	2%	2%	2%	2%
Ferrous Metals	3%	3%	3%	3%
Aluminum	3%	3%	3%	3%
Other Nonferrous Metals	3%	3%	3%	3%
Plastics				
PET	2%	2%	2%	2%
HDPE	2%	2%	2%	2%
PVC	2%	2%	2%	2%
LDPE/LLDPE	2%	2%	2%	2%
PP	2%	2%	2%	2%
PS	2%	2%	2%	2%
Other	2%	2%	2%	2%
Rubber and Leather				
Tires				
Other (dur. & non-dur.)	7%	7%	7%	7%
Textiles	10%	10%	10%	10%
Wood	20%	20%	20%	20%
Other	7%	7%	7%	7%
Food Wastes	70%	70%	70%	70%
Yard Trimming	60%	60%	60%	60%
Miscellaneous Inorganic Wastes	7%	7%	7%	7%

Table 4. Fossil Carbon Content (dry mass fraction)

Plastics	
PET	0.63
HDPE	0.86
PVC	0.38
LDPE/LLDPE	0.86
PP	0.86
PS	0.92
Other	0.66
Rubber and Leather	
Tires	
Other (dur. & non-dur.)	0.60
Textiles	0.39

Table 5. Biogenic Carbon Content (dry mass fraction)

Paper and Paperboard	0.32
Rubber and Leather	
Tires	
Other (dur. & non-dur.)	0.26
Textiles	0.02
Wood	0.41
Other	0.34
Food Wastes	0.23
Yard Trimming	0.38

Table 6. Calculated Carbon Content per Ton of Waste Incinerated (kg CO_2/ton)

	1990	2000	2010	2017
Fossil CO_2 Emission Factor	310	439	582	633
Biogenic CO_2 Emission Factor	530	487	389	358

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