EPA
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Summary of Expert Review Comments and Responses:
Draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018*

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Responses to Comments Received during the Expert Review Period on the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018*

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Preface

EPA thanks all commenters for their interest and feedback on the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks. To continue to improve the estimates in the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks, EPA distributed draft chapters of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018* for a preliminary Expert Review of estimates and methodological updates prior to release for Public Review. The Expert Review was 30 days by sector and EPA provided experts charge questions to focus review on methodological refinements and other areas 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.

EPA received 40 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 appendices to this document.

Chapter 3. Energy

Comment 1: Clarity and transparency of the Energy chapter
Overall, the data is conveyed clearly and concisely. The chapter could use further explanation regarding causes of trends or changes over time.

Response: EPA thanks the commenter for the review of the energy chapter of the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks. In terms of explanation regarding causes of trends or changes over time, Chapter 2 of the National Inventory Report (NIR), not included as part of Expert Review, includes a discussion of recent trends in emissions. Chapter 2 is included in the draft report published for a 30-day Public Review, but we may consider adding some trend context to the guidance memo in future reviews to facilitate review. Section 2.1 has a discussion of recent trends in energy emissions including CO_2 emissions from fossil fuel combustion. Section 2.2 highlights trends by economic sector including with emissions from electricity distributed to economic end-use sectors. The trends discussion in the energy chapter of the NIR (Page 3-8 of the Public Review draft report) has a similar discussion to what is in Chapter 2 and EPA can look into simplifying / improving the discussion across the different chapters for future reports.

Comment 2: Description of N_2O and CH_4 emission factors
It is worth including a concise description of emissions factors in the body of the chapter for N_2O and CH_4.

Response: Annex 3.1 of the NIR includes a complete description of the methodology for estimating CH_4 and N_2O emissions from stationary combustion, and Annex 3.2 includes the discussion for mobile combustion. The methodology discussion in the energy chapter for CH_4 and N_2O emissions does include a brief description of the factors used. However, due to the technology-dependent nature of the factors and the complexity involved, especially across different model years and vehicle types for mobile sources, the details on emission factors are presented in the annex for ease of readability of the main report.

Comment 3: CH_4 leakage
Is CH_4 leakage addressed elsewhere?

Response: Fugitive CH_4 emissions from coal mining are presented in Sections 3.4 and 3.5 of the NIR. Fugitive CH_4 emissions from petroleum systems are presented in Section 3.6, fugitive CH_4 emissions from natural gas systems are presented in Section 3.7 and fugitive CH_4 emissions from abandoned oil and gas wells are presented in Section 3.8 of the NIR.

Comment 4: Increased natural gas use
3-4 (5-20): The chapter claims that natural gas use increased for residential and commercial sectors, but that only explains about half of overall natural gas increase. The power sector had a substantial increase of about 15%, a 74 MMT CO_2 increase from natural gas and a 56 MMT CO_2 decrease for coal in the power sector. This is better addressed after the tables in lines 5-20.

Response: The EPA agrees with the comment and the language in the text has been modified to indicate that the increase in the residential and commercial sectors is total energy use not just direct natural gas use. This includes increased electricity use, which leads to more emissions from electricity production in the power sector.

Comment 5: Weather impacts on heating and cooling
3-5 (4-11): Was the weather that caused more heating and cooling an anomaly? Trend? Regression to mean (after two mild summer/winters). This is well addressed in Figure 3-6 on page 3-5, and could be stated in the text.

Response: EPA agrees with the comment and the text discussing the 2018 heating degree days was modified to clarify that even though 2018 HHD were higher than in 2017 they were still 5.7 percent below normal. Figure 3-6 was also updated to clarify the derivations from normal.

Comment 6: Transportation share of power use
3-7 (19): How is transportation's share of power use so high? It is similar to the combined power of residential and commercial.

Response: Table 3-8 in the Expert Review draft (pg 3-7) of the NIR includes both direct emissions and emissions from electricity use distributed to the end-use sectors shown, including transportation. The transportation emissions are high because of emissions related to direct energy use. Table 2-12 of the NIR shows the emissions by end-use sector broken out in terms of direct energy use and electricity-related energy use. The table shows that electricity-related emissions from the transportation end-use sector are small.

Comment 7: CH_4 emissions
3-8 (7): If CH_4 emissions are from incomplete combustion / leakage, we should specify. If it's calculated through a bottom-up calculation, we should specify.

Response: More information on CH_4 and N_2O calculations are provided starting on page 3-20 of the Expert Review draft. Furthermore, Annex 3.1 of the NIR includes a complete description of the methodology for estimating CH_4 and N_2O emissions from stationary combustion. The emissions are for only the combustion component of fuel use and represent for the most part incomplete combustion emissions. The calculations are based on an approach of fuel use by combustion technology multiplied by emission factors for that fuel and combustion technology type.

Comment 8: Carbon content of natural gas versus coal
3-10 (20): It is worth adding the approximate carbon content per kWh of natural gas versus coal to explain the impact of transitioning to natural gas.

Response: Page 3-3 of the Expert Review draft includes more information on the carbon content of different fuels, which helps explain the impact on emissions of transitioning from coal to natural gas.

Comment 9: Emissions direction confusion
3-11 (1-8): These lines are confusing; the text suggests there was both an increase and decrease in emissions over timeframe.

Response: EPA agrees with the comment and the text indicating there was a decrease in emissions has been deleted. Emissions from the electric power sector increased from 2017 to 2018.

Comment 10: Increase in CO_2 emissions with respect to cooling and heating degree days
3-13: In Figure 3-11, what explains the increase of residential and commercial CO_2 emissions with respect to cooling and heating degree days between 1997 and 2011?

Response: Figure 3-11 is not meant to highlight long-term trends in residential and commercial energy use and emissions, but rather highlight how some of the annual fluctuations are tied to heating degree day (HDD) and cooling degree day (CDD) changes. To understand the type of trends identified in the question concerning increase in emissions with respect to HDD and CDD between 1997 and 2011 would require a further understanding of energy end use requirements over time. Emissions are generally tied to total energy use and are impacted by building energy efficiency, building stocks, types of energy use and GHG intensity of energy sources. That type of analysis is beyond the scope of the National Inventory Report.

Comment 11: Developing estimates of EV energy use

I have no major comments except for the need to develop bottom-up estimates of energy consumption and GHG emissions from on-road electric vehicles for inclusion in end-use sector values (as well as the table traditionally at the end of Chapter 2 summarizing Transportation-Related GHG Emissions). Proposed methods and data have been outlined in an Argonne National Laboratory Report, Impacts of Electrification of Light-Duty Vehicles in the United States, 2010-2017, available at https://publications.anl.gov/anlpubs/2018/01/141595.pdf.

Response: EPA agrees with the comment and energy use and emissions associated with electric vehicle use has been incorporated into the NIR for the transportation electricity end-use sector. The approach is generally consistent with the Argonne report and is outlined in the memo: Browning, L. (2018a). Updated Methodology for Estimating Electricity Use from Highway Plug-In Electric Vehicles. Technical Memo, October 2018.

3.1 Fossil Fuel Combustion: CO_2 from Fossil Fuel Combustion

Comment 12: Clarity and Transparency of CO_2 from Fossil Fuel Combustion Discussion
The methodology is thoroughly explained. If the carbon intensity of different energy sources themselves have changed much over time, it is worth including in Box 3-5 on page 3-17.

Response: The carbon intensity of fossil fuels themselves do not vary that much over time as is further described in Annex 2 of the NIR.

Comment 13: Data Source for Energy Use of U.S. Territories
We're not sure of any other data sources that could be used.

Response: EPA appreciates the response and continues to investigate other data sources of U.S. territory energy use.

Comment 14: GHGRP facility-level combustion emissions data
This data still needs to be updated.

Response: EPA appreciates the response and the GHGRP data has been updated for the Inventory final report. EPA continues to review the use of GHGRP data as discussed in Box 3-4 of the NIR.

3.2 Fossil Fuel Combustion: CH_4 and N_2O from Stationary Combustion

Comment 15: CH_4 and N_2O emission factors for the electric power sector
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?

On Line 5 of 3-14, the text states that CO_2 is estimated in line with Tier 2 methodology. This seems to contradict the first sentence of the question above.

Response: The first sentence in the question above is referencing a Tier 1 methodology used for non-electric power CH_4 and N_2O sources. Line 5 of page 3-14 of the expert review draft is referencing CO_2 emissions (not CH_4 and N_2O) and CO_2 emission estimates for all sources use a Tier 2 approach.

3.2 Fossil Fuel Combustion: CH_4 and N_2O from Mobile Combustion

Comment 16: Update to CH_4 and N_2O factors
The proposed approach of estimating CH_4 and N_2O mobile source EFs directly from annual certification data seems to be a step forward from the current regression-based approach. EPA is commended for this update and improvement.

Response: EPA appreciates the comment and continues to look for ways to improve the accuracy of emission factors used in the analysis.

3.2 Carbon Emitted from Non-Energy Uses of Fossil Fuels

Comment 17: Clarity and transparency of CO_2 from Fossil Fuel Combustion discussion
Stored carbon versus released carbon in non-energy products is well explained in the section.

Response: EPA appreciates the comment and continues to investigate ways to improve the transparency and clarity of the NEU discussion in the NIR.

Comments on gasoline C factor update memo

Comment 18: Speciated gasoline component data
EPA is commended for developing a new method for estimating this EF, particularly in light of the unavailability of NIPER gasoline composition data since 2009. The proposed approach seems to make sense in concept, although it is not clear if the API data can be used to speciate gasoline components or represent changes in gasoline speciation over time.

Response: EPA appreciates the comment and has identified additional data and methodologies relevant to this gasoline C factor update. EPA is still reviewing the additional data and possible approaches and therefore the gasoline C factor was not updated in this year's final inventory report. EPA is still considering the update for future Inventory cycles and data will be recalculated as needed if factors change.

Comment 19: Speciated gasoline data
EPA's use of the gasoline speciation data collected in conjunction with the API 2010 E10 blending study is supported. It should be recognized that the fuels evaluated as part of the API study are representative of the 2008-2009 timeframe. Ideally, it would be better to generate data from a new or more current nationwide study of the ultra-low sulfur gasoline/BOBs now being used to make E10, but such data are not available, so the API 2010 study is the best alternative. The use of surrogate compounds to represent or estimate the carbon content of different components of US motor gasoline fuels is not recommended.

Response: EPA appreciates the comment and has identified additional data and methodologies relevant to this gasoline C factor update that could be more relevant over time. EPA agrees that use of surrogate compounds to represent gasoline components is not advisable and is considering alternate methods beyond what was outlined in the expert review memo. EPA is still reviewing the additional data and possible approaches and therefore the gasoline C factor was not updated in this year's final inventory report. EPA is still considering the update for future Inventory cycles and data will be recalculated as needed if factors change.

Comment 20: Use of speciation data
The approach outlined in Annex 2 of the expert review memo to develop the speciated gasoline components is generally supported. However, in the Annex, EPA indicated that it picked 2 gasolines from the data supplied by API which it deemed to be representative of winter and summer gasoline fuels. It would have been useful to do a sensitivity analysis of the results based on fuels from the API data set that represented a range of summer gasoline compositions and a range of winter gasoline compositions.

Response: EPA appreciates the comment and has identified additional data and methodologies relevant to this gasoline C factor update that could be used to represent gasoline components and is considering alternate methods beyond what was outlined in the expert review memo. EPA is still reviewing the additional data and possible approaches and therefore the gasoline C factor was not updated in this year's final inventory report. EPA is still considering the update for future Inventory cycles and data will be recalculated as needed if factors change.

Comment 21: Use of EPA Trends Report
The proposed use of the EPA Trends data is an improvement over the status quo. However, it is not clear when the EPA Trends report will be updated. Data on the regular gasoline surveys that was used to produce the Trends data is available on an ongoing basis online at https://www.epa.gov/fuels-registration-reporting-and-compliance-help/public-data-gasoline-programs under the heading "Gasoline Batch Report Data." This data seems likely to be more current than the Trends report.

Response: EPA agrees with the comment that the gasoline batch data is more up to date than the EPA trends report data and will consider that as a source of information for updating the gasoline C factor. Furthermore, EPA has identified additional data and methodologies relevant to this gasoline C factor update. EPA is still reviewing the additional data and possible approaches and therefore the gasoline C factor was not updated in this year's final inventory report. EPA is still considering the update for future Inventory cycles and data will be recalculated as needed if factors change.

Comment 22: Use of EPA Trends Data
The EPA Trends data provide an adequate basis for evaluating and estimating historical changes in the composition of motor gasoline during the 1990 to 2018 time period. In the interest of maintaining data consistency, the use of the EPA Trends data is supported for the full time series under evaluation, not just for years where the NIPER data are not available. There are other sources of data available that EPA could use to "spot check" the patterns observed in the EPA Trends data. The twice-yearly survey of North American motor gasoline properties that has been conducted by the Alliance of Automobile Manufacturers (AAM) for over 20 years is one such example.[1] However, the results of the AAM survey are not freely available to the public.

Response: EPA appreciates the comment concerning the trends data and has identified a source of the data that is more up to date than the EPA trends report referenced in the expert review memo and will consider that as a source of information for updating the gasoline C factor. EPA also appreciates the reference to the AAM survey as a potential source of gasoline composition data. Furthermore, EPA has identified additional data and methodologies relevant to this gasoline C factor update. EPA is still reviewing the additional data and possible approaches and therefore the gasoline C factor was not updated in this year's final inventory report. EPA is still considering the update for future Inventory cycles and data will be recalculated as needed if factors change.

Chapter 4. IPPU

4.16 Phosphoric Acid Production

Comment 23: Phosphoric acide production facility locations
On line 12 of page 4-29, Texas and Louisiana can be removed from the list of states with facilities that use imported phosphate rock for phosphoric acide production. Plants in Texas and Louisiana have been closed permanently.

Response: EPA agrees with this suggested update and has reflected this change in the Final Inventory report.

[1] https://autoalliance.org/energy-environment/fuel-publications/

Comment 24: Phosphate rock used to manufacture elemental phosphorous and other phosphorous- based chemicals

On line 18 of page 4-31, the text indicates that 7 percent of domestically-produced phosphate rock is used to manufacture elemental phosphorous and other phosphorous-based chemicals, rather than phosphoric acid. This percentage was less than 5 percent in 2017.

Response: EPA appreciates this clarification and has updated the uncertainty and time series consistency discussion to reflect this information in the Final Inventory report.

Chapter 5. Agriculture

5.2 Manure Management

Comment 25: B_0 values for waste characteristics data
Based on a meta-analysis and some newer literature it seems that the values in Table A-185 on page A-37 may need to be adjusted and perhaps having B_0 value for each species may not be appropriate. For example, values for the liquid fraction of dairy manure and dairy lagoon have B_0 closer to 0.5 which may help explain some discrepancies found comparing on-farm data to estimated data, see discussion below.

Reference	species	methane (m3/kg vs)	HRT (days)	temp	storage type	method
Habtewold et al., 2017	dairy liquid	0.268	160		tank	
Rosenberg and Kornelium, 2017	beef cattle	0.24	40			
Miranda et al.	dairy cattle	0.4 - 0.44			lagoon	
Rico et al	dairy cattle	0.258	90	35	solid fraction	batch reactor lab
Rico et al	dairy cattle	0.307			manure	batch reactor lab
Rico et al	dairy cattle	0.371	45		screened manure	batch reactor lab
Rico et al	dairy cattle	0.604			liquid fraction	batch reactor lab
Rico et al	dairy cattle	0.58			liquid fraction	batch reactor lab

Emissions from Anaerobic Lagoons

Recent research has suggested that methane (CH_4) emissions from liquid manure storage may be greater than is estimated using current USEPA (which follows IPCC) methodology (Wolf et al., 2017; Leytem et al., 2017 Balde et al., 2016; Owens and Silver, 2015; Lory et al., 2010). These discrepancies are likely due to several factors related to management and the factors used in the emissions calculations. The simplified equation used to estimate CH_4 generation from anaerobic lagoons is as follows:

$CH_4 = VS \times B_0 \times MCF \times 0.67 \times MDP$*
*MDP is used in the USEPA equation not the IPCC

Where CH_4 is the emissions in kg month-1, volatile solids (VS) is the amount of VS entering the lagoon (kg), B_0 is the maximum CH_4 producing capacity of the manure (m^3 CH_4 kg VS-1), MCF is the methane conversion factor, 0.67 is the density of CH_4 at 25° C (kg CH4 m-3 CH4), and the MDP is the management and design practices factor utilized by USEPA (0.8). Comparison of on-farm emissions vs. CH_4 estimation utilizing these equations has found that emissions

from liquid storage (anaerobic lagoon and tanks storage) are almost double what is estimated using this equation. Emissions estimates are close to those measured on farm in peak summer, but underestimate emissions during the remainder of the year.

There are several factors that could account for these large discrepancies between estimated and measured emissions. The inventories assume that all the liquid is going into a lagoon unless there is mechanical separation in which case that manure VS content is removed from the estimation. On many dairies, the use of earthen settling basins is common, where manure flows through the basin to settle solids before reaching the main lagoon. The settling basins behave differently than the main lagoons and in effect, in many cases, act like small digesters producing large amounts of CH_4 (Leytem et al., 2017; Arndt et al., 2018) yet due to the complexity of the liquid handling systems these are not accounted for in inventory methods. The inventory method also assumes a complete cleanout of the lagoon systems each fall. In many anaerobic lagoons, most of the water is pumped out during the year, however, sludge at the bottom may not be removed in many cases. In addition, the settling basins may be cleaned out very infrequently. Therefore, there is likely unaccounted VS remaining in the system that are available for breakdown over time as well as serving as a constant inoculum, which maintains high levels of CH_4 generation even after the lagoons are pumped out. A lag phase in CH_4 emissions of up to 50 d has been noted in the literature when manure is stored in clean tanks after which CH_4 emissions increase exponentially (VanderZaag et al. 2010a). However, modifying the estimation equation to try and account for VS carryover did not fully account for the discrepancy in CH4 emissions (Leytem and Arndt personal communication).

When one uses the monthly timestep equation for estimating monthly CH_4 emissions per Mangino et al. (2001), the emissions curve follows a trend that would be expected for a batch reactor with low emissions early in the year then spiking in the summer and then falling again to very low emissions rates in fall and winter. However, on farm research has indicated that emissions from anaerobic lagoon systems has less of a fluctuation in emissions, trending seasonally with temperature, but maintaining higher rates of CH_4 production in spring and fall than indicated using the Magino et al., method. This suggests that the emissions factors used (B_0 or MCF) may underestimate emissions. The B_0 values used in the USEPA (IPCC) emissions estimates were derived from research on the biological activity of CH_4 digesters (Bryant et al., 1976; Morris, 1976; Hashimoto et al., 1981; Hashimoto, 1983) which may not be representative of anaerobic lagoons. The broader microbial community, longer VS residence times, and lower loading rates of uncovered anaerobic lagoons may lead to higher VS degradation rates than those found in anaerobic digesters (Lory et al., 2010). According to a review of the literature, Lory et al. (2010) surmised that a properly operating uncovered anaerobic lagoon can break down solids to a higher degree than is predicted using anaerobic digester models. Therefore, B_0 may underestimate the potential amount of CH_4 generated from these lagoons and therefore underestimate overall CH_4 emissions. Based on their literature search, they reported VS degradation rates of 0.45 to 0.72 kg kg-1 VS added for dairy cows and up to 0.88 for swine. The MCF values may also underestimate emissions. The MCF is strongly influenced by temperature and assumes very little CH_4 production during colder times of the year which may underestimate emissions from anaerobic lagoons, particularly in colder climates. Another factor to consider is the amount of degraded VS that is converted to CH_4 which has also been shown to vary with literature reports ranging from 0.45 to 0.85 m3 kg-1 VS destroyed (Lory et al., 2010). Craggs et al. (2008), also reported a VS removal rate of 59% from an anaerobic dairy lagoon in New Zealand and a biogas production rate of 0.44 (m3 kg-1 VS removed), which is very similar to those estimated by Lory et al. (2010). Therefore, Lory et al., (2010) proposed an alternative estimation method:

$CH_4 = VS \times VSDF \times B' \times 0.662$

Where CH_4 is the emissions in kg year-1, VS is the total volatile solids excreted that is going to the lagoon (kg), VSDF is the fraction of VS broken down in storage (kg VS destroyed kg-1 VS added; 0.57), B' is the volume of CH_4 generated on a VS destroyed basis for the lagoon (m3 CH_4 kg-1 VS destroyed; 0.45 – 0.85), and 0.662 is the density of CH_4 at 25° C (kg CH4 m-3 CH_4). This estimation equation worked well for an anaerobic dairy lagoon in Idaho, USA (measured on farm = 14,594 kg CH_4 yr-1 vs. estimated 10,495 – 19,824) however this is only one comparison.

It appears as if the current equation for estimating emissions from anaerobic lagoons needs to be updated, however, determining the appropriate factor to change is difficult. One could increase the MCF, however in many cases it may need to be greater than 100% to account for on-farm emissions. The alternative is to increase B_0, recognizing that anaerobic lagoons are more likely to break down more VS, therefore generating more CH_4, than is

estimated using the current value. A value of B_0 close to 0.50 may be more representative (for dairy) than the current value of 0.24. However, there still remains a very limited on farm dataset for validating alterations in the equations.

Response: See response to Comment 30.

Comment 26: Estimated volatile solids (VS) and total nitrogen excreted (Nex) production rates by state for cattle (other than calves) and American bison

The values in Table A-187 on page A-40 look a bit high. For example, VS for dairy cattle for Idaho are listed at 2,920 kg/animal/yr. If I use the ASABE 2005 values, this would be 2,582 or if I used the current IPCC default value it would be 2,037.

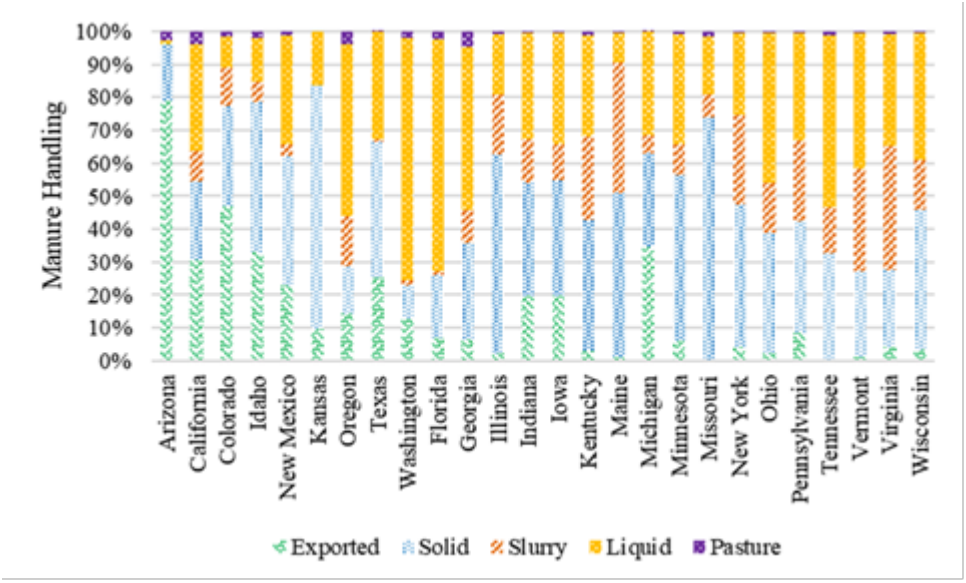
The nitrogen excretion values also look high. I will use Idaho as an example again, the value is 162 kg/animal/year. I calculate 138 kg/animal/year using some of the latest equations and assuming that cows are lactating for 305 days and dry for 60 with a birth weight of 680 (136 kg/animal/year for a birth weight of 600 which I think is closer to reality). Also, I calculate 50 kg/animal/d for heifers while a value of 69 is in the table. Below are the equations and references that I used.

Nitrogen excretion by lactating cattle							
NE = 20.3 + 0.654*NI			Reed et al., 2015				
NE = 7 + 0.710*NI			Yan et al., 2006				
NE = 30 + 0.67*NI			Kebreab 2010				
NE = (DMI *CP *84.1) + (BW x 0.196)				Nennich et al. 2005			
Lactating data averages							
DMI (kg)	CP (%)	NI (g/d)	BW (kg)	N excretion g/d/cow	N excretion kg/d/1000kg		ref
21.785	16.6	578.6096	600	398.7107	0.664518		Reed et al., 2015
21.785	16.6	578.6096	600	417.8128	0.696355		Yan et al., 2006
21.785	16.6	578.6096	600	417.6684	0.696114		Kebreab 2010
21.785	16.6	578.6096	600	421.7317	0.702886		Nennich et al. 2005
				413.9809	**0.689968**	average	
Nitrogen Excretion by Dry cows							
NE = 15.1 + 0.828*NI			Reed et al., 2015				
Dry Cow data averages							
DMI (kg)	CP (%)	NI (g/d)	BW (kg)	N excretion g/d/cow	N excretion kg/d/1000kg		
8.205	15.45	195	690	**176.56**	**0.255884**		Reed et al., 2015
Nitrogen Excretion by heifers							
NE = 15.1 + 0.828*NI			Reed et al., 2015				
NE = (DMI * CP * 78.39) + 51.4			Nennich et al. 2005				
Heifer data averages							
DMI (kg)	CP (%)	NI (g/d)	BW (kg)	N excretion g/d/cow	N excretion kg/d/1000kg		
7.175	14.4	159	531	146.752	0.276369		Reed et al., 2015
7.175	14.4	159	531	132.3925	0.249327		Nennich et al. 2005
				139.5723	**0.262848**	average	

Response: See response to Comment 30.

Comment 27: 2018 manure distribution among waste management systems by operation

I am concerned about the accuracy of the values in Table A-188 on page A-41. The figure below was generated by a post-doc working in the ARS lab in Pennsylvania, based on the ARMS data. It is total mass of manure on dairies in different storage. To me, this distribution looks a lot more realistic for Idaho at least if I assume 100% of the manure exported was a solid. When I did my own "survey" I came up with about 76% of total manure stored as a solid. Discrepancies for other major dairy states are also present compared to this.



There also seems to be other manure data in ARMS so I am a bit perplexed by it. This would obviously have a very large impact on the values calculated and I think more work in this area could be done.

Response: See response to Comment 30.

Comment 28: Methane conversion factors for dry systems
Below are the most recent values in the new IPCC refinement that differ from Table A-191 on page A-45.

Waste Management System	Cool Climate MCF	Temperate Climate MCF	Warm Climate MCF
Cattle deep litter (<1month)	2.75	6.5	18
Cattle deep litter (>1month)	21-26	37-41	73-76
Composting static pile	1	2	2.5
Composting Extensive/passive	1	2	2.5
Dry Lot			2

They also had a new value for pasture of 0.45 but that was assuming you used a B_0 of 19.

Response: See response to Comment 30.

Comment 29: Direct N_2O emission factors
Below are the most recent values in the new IPCC refinement that differ from Table A-193 on page A-47.

Waste management system	Direct N_2O EF

Anaerobic Digester	0.0006
Composting intensive	0.005
Composting Passive	0.005
Composting Static (force aeration)	0.10
Liquid/slurry	0.005 w/ cover 0/without
Solid Storage	0.010

Response: See response to Comment 30.

Comment 30: Indirect N_2O loss factors

One basic question here, % of what lost? Total N from the storage? N fed? Below are the most recent values in the new IPCC refinement that differ from what you have in the current table.

Do you account for additives such as Alum that will greatly reduce NH_3 emissions?

Animal Type	**Waste Management System**	**Volatilization Nitrogen Loss**
Beef Cattle	Dry Lot	30*
Beef Cattle	Liquid/Slurry	15
Beef Cattle	Pasture	7
Dairy Cattle	Anaerobic Lagoon	35**
Dairy Cattle	Daily Spread	7
Dairy Cattle	Deep Pit	25
Dairy Cattle	Dry Lot	45
Dairy Cattle	Liquid/slurry	48
Dairy Cattle	Solid Storage	30
Poultry	Anaerobic Lagoon	40
Poultry	Liquid/slurry	40
Poultry	Manure with bedding	40#
Poultry	Manure without bedding	48
Poultry	Solid Storage	40
Swine	Anaerobic Lagoon	40
Swine	Deep Pit	25
Swine	Liquid/Slurry	48

*Research shows that ~50% of N fed is lost as NH_3 from feedlots.

**Our on-farm research has shown that 65 percent of total N was lost from lagoon storage over the year (Leytem et al., 2018).

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Response: EPA appreciates the commenter's suggestions to improve the accuracy and clarity of the chapter describing GHG emissions from manure management (Chapter 5.2) and recognizes the commenter's specific data recommendations to potentially improve emissions estimates. EPA is regularly reviewing literature and available data sources for updated activity data including methane producing potential, volatile solids and nitrogen excretion rates, waste management system usage data, methane conversion factors, and emission factors. Note that volatile solids and nitrogen excretion rates for cattle are reliant on underlying data provided in Chapter 5.1 (Enteric Fermentation), which EPA acknowledges is also an area for potential improvements. EPA appreciates the commenter for confirming known available data and applicable references; EPA will review these items as resources allow. EPA is aware of IPCC's 2019 Refinement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories and plans to review updated methodologies and emission factors as resources allow, as noted in the Planned Improvements section of Chapter 5.2.

Chapter 6. LULUCF

No comments received.

Chapter 7. Waste

Landfill Specific

Comment 31: Pulp and paper industrial wastewater and landfill emissions

NCASI independently calculated pulp and paper industrial wastewater CH_4 emissions given in Table 7-11 on 7-23 of the draft report (the value reported is 0.6 MMT CO2eq.), and NCASI's result conforms to the pulp and paper result in Table 7-11. NCASI appreciates the high level of quality in the draft report regarding pulp and paper industry wastewater CH_4 emissions.

NCASI calculated CH_4 emissions of 4.5 MMT CO_2eq. from pulp and paper industrial landfills using 2018 EPA GHG reporting program (GHGRP) data. Within the draft report, NCASI could only locate CH_4 emissions from all industrial landfills (15.0 MMT CO_2eq. for 2018 found in Table 7-3 on 7-3). NCASI would appreciate confirmation that the 4.5 MMT CO_2eq. from pulp and paper industrial landfills that NCASI calculated from GHGRP data is the same number EPA is using for their calculations for CH_4 emissions from all industrial landfills.

Response: EPA appreciates the commenter's feedback regarding the accuracy of the pulp and paper industrial wastewater methane emissions estimates. With regard to the emissions estimates for pulp and paper industrial landfills, EPA added text to the section titled "Methodology Applied for Industrial Waste Landfills," within section 7.1 of the Inventory text, to clarify that EPA is currently unable to use the net emissions data directly reported to the GHGRP for industrial landfills because the waste disposal information does not correlate well for all industrial waste landfills accounted for in the Inventory estimates. Therefore, EPA is maintaining our current approach to estimating emissions from industrial waste landfills using production data from the pulp and paper and food and beverage sectors.

Comment 32: Datasets of quantities of industrial food processing waste disposed of in industrial waste landfills
EPA conducted an analyses of industrial food processing waste[1] in 2012. According to that report, although solid waste management data is not available, the primary method for managing solid waste from food processing sector is for utilization. These include animal feed, raw material for other products or direct utilization on agricultural land. Given the report's suggestion that very little food processing waste is landfilled, it would also be unlikely that food processors would spend the own or operate industrial landfills. The little food waste that is generated would more likely be redirected for composting or to a municipal solid waste landfill. This comports with industry experience.

The industry also evaluated the dataset for industrial waste landfills and found that very few of them represent food waste processing landfills. Those that do are primarily sugar facilities. In addition, for facilities that were unclear, we queried a few of the large generators that report under subchapter TT. Based on responses received, none of them are food waste facilities.
Response: EPA notes the information provided by the commenter on industrial food processing waste, including the EPA analyses from 2012. In the next Inventory cycle, EPA will further investigate the prevalence of food-related waste deposited in industrial waste landfills. EPA intends to record any findings from this exercise in a memorandum and if any changes to the methodology or assumptions for industrial waste landfills are warranted, EPA will implement the changes. Please see the "Planned Improvements" in Section 7.1.

Comment 33: Unpublished waste characterization studies from 1990
EREF has a assembled a comprehensive list of waste characterization studies including those evaluated by EPA. They plan on using reliable data from those studies to reevaluate the DOC values for the duration of the period from 1990 onward. This analysis will inform updates to the 2016 paper provided to EPA and reinforce industry's previous request to update the GHGRP as well as the US GHG Inventory specifically for years 2005-present. EREF expects to conclude its update to the White Paper by February 2020.

We understand that EPA is focused on the period from 1990-2004 because it falls outside the GHGRP timeframe. However, data from waste characterization studies indicate the MSW fraction in the waste stream has steadily declined since around 2000. As previously stated, EREF obtained additional information to further substantiate the steady decline in the MSW fraction of waste disposed of in MSW landfills necessitating updates to the DOC values for 2005 to the present to more accurately represent landfill emissions. Therefore, EPA should extend the time period from 2005 to current. We also request EPA to update the GHGRP with revised DOC values for calculating MSW Landfill emissions.

Response: EPA notes the commenter's feedback on the decline in the MSW fraction of waste disposed in MSW landfills. EPA looks forward to reviewing the work by EREF to update their 2016 paper. As stated in the Planned

Improvements section of Section 7.1 of the U.S. Greenhouse Gas Inventory of Emissions and Sinks, EPA is developing a multivariate analysis using publicly available data directly reported to the GHGRP solving for optimized DOC and k-values across the more than 1,100 landfills that reporting to the program. The results of this analysis could help inform a future GHGRP rulemaking where changes could be made to the default DOC and k-values contained within Subpart HH of the GHGRP which could then be carried over to the Inventory emissions estimates for MSW landfills upon promulgation of any revisions to 40 CFR Part 98.

Comment 34: Decay rate values

The attached article provides information on additional first order decay models for landfill gas production. It describes two Dutch models; one from TNO (The Netherlands Organization of Applied Scientific Research) and another from Afvalzorg (Dutch waste company).

Response: EPA appreciates the articles provided by the commenter and will review them in the context of Planned Improvements to the Inventory estimates.

Comment 35: Scale-up factor methodology for landfills

We find the explanation of the methodology EPA employed to arrive at the scale-up factor to be clear. However, based on reasonable expectations that landfills that do not report under the GHGRP are likely to be smaller, closed sites with declining GHG emissions and that reporting landfills will continue to represent a larger proportion of WIP, we recommend that EPA routinely evaluate and revise the scale-up factor. For example, since starting in 2010, every year fewer landfills report more than the 25,000 MT CO_2eq. Yet, every year, more landfills are included in the GHGRP. This means that more of the waste is covered by reporting facilities on an annual basis.

Year	# of landfills reporting	# of landfills >25k MT CO_2eq.	Total MT CO_2eq. reported
2010	1235	975	101,920,033
2011	1240	965	93,830,839
2012	1252	961	94,375,699
2013	1278	946	91,159,615
2014	1290	941	90,817,217
2015	1294	935	89,746,871
2016	1300	914	86,905,137
2017	1304	898	86,464,158
2018	1313	896	89,215,401

Again, most landfills that are exempt from the GHGRP requirements are old, small, closed landfills. The potential methane emissions from these sites decrease year over year by approximately 3 percent, on average. Therefore, the emissions contribution from these sites will continue to decrease compared to the sites that report via the GHGRP. The scaling factor must be adjusted to reflect the declining contribution of the exempt sites.

Response: EPA appreciates the commenter's feedback on the clarity of the methodology used to develop the scale-up factor to account for landfills that do not report to the GHGRP. EPA also agrees with the commenter's feedback that the scale-up factor should be evaluated on a routine basis. There is a large amount of uncertainty associated with the number of non-reporting landfills and their total waste-in-place and the scale-up factor is our best estimate given the available information. EPA plans to reexamine the scale-up factor for the 1990-2019 Inventory cycle to determine if there are additional landfills reporting to the GHGRP such that the waste-in-place amounts for those landfills can be removed from the scale-up factor assumptions. As the same time, EPA will also account for those landfills that have stopped reporting to the program because they were able to exercise the off-ramp. Any additional information from commenters on landfills that do not report to the GHGRP that could help refine the scale-up factor assumptions are always welcome and appreciated.

Comment 36: Methane oxidation factor

Our previous years' comments on methane oxidation factor used for the period 1990 – 2004 in the inventory time series remain unchanged and are repeated below. EPA calculates a national estimate of methane generation and emissions using a combination of secondary data sources that detail the annual quantity of waste landfilled and the annual quantity of methane recovered from facilities with landfill gas collection and control systems. EPA applies a 10% oxidation factor to all facilities for the years 1990 to 2004. This ten percent default factor contrasts significantly with the average methane oxidation factor of 19.5 percent applied through use of GHGRP data, to the later years of the time series (2005 to 2016). Importantly, the 19.5 percent average oxidation rate incorporated in the GHGRP, subpart HH emissions data is premised on a more detailed and up-to-date estimation approach than is the default value of 10 percent. It is also a conservative average value, as the GHGRP methodology restricted the maximum oxidation rate to 35 percent.

In its work to review and revise the method for calculating methane oxidation under subpart HH of the GHGRP, EPA acknowledged the need to update the default 10 percent oxidation value. The default value was based on only one field study, at a landfill without gas collection and control, and did not reflect the much higher oxidation values found in numerous subsequent, peer-reviewed field studies. Given the plethora of scientific studies showing methane oxidation to be several times higher than the EPA and IPCC default value, we strongly recommend EPA apply a revised value (perhaps the average oxidation value from the GHGRP) to the earlier years of the time series.

Response: ***EPA appreciates the commenter's feedback on the oxidation factor as applied to estimating emissions from MSW landfills. EPA regularly reviews new literature related to landfill methane oxidation and investigated options to adjust the oxidation factor from the 10 percent currently used for 1990 to 2004 to another value or approach such as the binned approach used in the GHGRP (e.g., 10 percent, 25 percent, or 35 percent based on methane flux) or the average oxidation factor across facilities reporting to the GHGRP (approximately 19.5 percent). At this time EPA has decided not to revise the methane oxidation factor for the 1990-2004 time series since such a change will likely result in a noticeable discontinuity in the emissions between 2004 and 2005-2010 (i.e., a jump in emissions between 2004 and 2005) that would need to be investigated and resolved to ensure methodological consistency over the time series and to accurately reflect trends. We continue to advance efforts to improve the methane generation calculations in the landfills section of the Waste Chapter by focusing on improvements to the DOC and k-value per responses to other comments submitted by this commenter, in order to make best use of the available resources across the Inventory compilation process.***

Comment 37: Degradable organic carbon (DOC)

Chapter 7 of the draft inventory explains that EPA uses one DOC value of 0.20 to calculate emissions for the years 1990 through 2004, and uses emissions reported through the GHGRP for years 2005 through 2017. The GHGRP allows landfills to use 0.20 for bulk MSW or allows a landfill to further delineate waste streams by accounting for separate shipments of C&D waste, which uses a DOC of 0.08, and separate shipments of inert wastes, which may use a DOC of 0.0. If a landfill delineates in this way, it must use a DOC of 0.31 for its MSW waste volumes, which applies an artificially high DOC to MSW, and inappropriately overestimates emissions. The required DOC value of 0.31 fails to account for the significant volumes of C&D and inert wastes that are incorporated in MSW, and which cannot be separated from the MSW or accounted for distinctly, as can discrete shipments of inert wastes from industrial or C&D recycling facilities.

While we are pleased to learn that EPA plans to revisit the DOC value of 0.20, we question why the Agency is focusing first on the early years of the inventory rather than the later portion of the time series. We believe that the fundamental shifts in the characterization of waste disposed in landfills has occurred in the later portion of the time series and that the research conducted thus far by state agencies and the Environmental Research and Education Foundation (EREF) are illustrative of those changes. We strongly recommend that EPA instead first focus on the second half of the time series and reevaluate the DOC values incorporated in subpart HH of the GHGRP, which underpins the data used for those years of the inventory.

In 2016, the Environmental Research and Education Foundation (EREF) undertook a state-based study of DOC values for both landfills receiving only MSW (MSW Only Landfills) and for Non-MSW Material going to MSW Landfills. EREF updated the 2016 paper in January 2019 with additional information and is again in the process of making further revisions based on new waste characterization information. The DOC guideline recommended by EPA for MSW Only Landfills is 0.31 and the recommended guideline for bulk material (combined MSW, C&D and inert waste streams) going to MSW landfills is 0.20. EREF concluded both of these guidelines over-estimate the amount of organic waste deposited in landfills, which results in inaccurate estimates of landfill gas generation and methane emissions. Furthermore, neither of the EPA-recommended DOC values have been reviewed in many years. It is time EPA update the DOC values for MSW and Bulk waste and we believe that the most valuable focus would be to reassess the DOC values incorporated in the GHGRP used for inventory years 2005 forward.

EREF reviewed 17 recent waste composition studies for MSW Only Landfills conducted by 13 states and confirmed that waste composition has and continues to change over time, as fewer organic materials are sent to MSW landfills. Since EPA cites the EREF research as a rationale for reassessing DOC values for 1990-2004, the following quotes from EREF clearly suggest that the data strongly suggest reevaluating DOC values used in the GHGRP for years 2005 and later:

> All characterization studies had DOC_{MSW} values significantly less than the default value of 0.31, which suggests this value is not representative of real-world conditions for MSW (Table 3; Figure 4). Analysis of U.S. EPA data … also results in a significantly lower DOC_{MSW} value compared to the U.S. EPA guideline of 0.31, with DOC_{MSW} values ranging from 0.218 in 1994 to a minimum of 0.160 in 2015 (Figure 4; Appendix B). Both the state characterization studies and U.S. EPA Facts and Figures data independently suggest that a DOC guideline value of 0.31 for MSW is not representative of the landfilled MSW stream. …
>
> The use of a single DOC value as a guideline for all U.S. landfills makes the implicit assumption that waste composition does not change over time or due to location. The results presented here suggest these are not valid assumptions and that, collectively, the use of a static DOC value of 0.31 may lead to inaccurate estimates of landfill gas emissions for landfills that only accept MSW. Because this specific analysis is focused only on MSW materials, one would expect the inclusion of non-MSW materials going to a landfill to impact DOC estimates even more.[2]

With respect to Non-MSW going to MSW Landfills, EREF finds "a common assumption is that all waste materials entering MSW landfills consist only of MSW materials. As noted previously, MSW Landfills rarely accept MSW exclusively. Rather, most MSW Landfills (landfills in 45 states) are authorized to accept other Subtitle D wastes in addition to MSW."[3] In addition, EREF notes:

> Given that a third of incoming waste to MSW Landfills consists of non-MSW materials, there is significant potential for non-MSW materials to impact the relative fraction of organics and degradable organic carbon (DOC) of the MSW Landfill waste stream.[4]
>
> The amount and types of non-MSW Subtitle D organic wastes impact the DOC value for the landfilled waste since it consists of both MSW and non-MSW streams. This combined DOC value (DOC_{SubD}) incorporates degradable organic carbon from all Subtitle D wastes accepted at MSW Landfills (both MSW and non-MSW). … State waste characterization studies were used to estimate the relative fraction of each organic constituent for C&D and industrial waste … and DOC for each waste type was calculated using Equation 1b. Based on this analysis the DOC_{SubD} value of landfilled waste is 0.167 (Table 7)."[5]

EREF also highlights that the DOC_{SubD} value:

> … is lower than the guideline value of 0.20 for bulk waste. It is also lower than the average DOC_{MSW} value of 0.191 computed in the prior section, indicating the inclusion of non-MSW decreases overall DOC. Using the

> same approach as for the DOC_{MSW} analysis, state-specific organics content and DOC_{SubD} values for all fourteen states with sufficient data were determined and presented in Table 8, below. … The results, all for 2013, highlight differences in DOC_{SubD} based on locale and suggest the use of a static 0.20 guideline for bulk waste may lead to inaccurate estimates of methane generation and emissions, especially in some areas.[6]

Thus, EREF concludes as follows:

> The average computed DOC value for MSW using state data was 0.191, or roughly three-fifths of the MSW guideline value. The average computed DOC value for bulk waste using state data was 0.167, or roughly four-fifths of the bulk waste guideline. This analysis suggests that the U.S. EPA's guideline DOC values of 0.31 for MSW-only landfills and 0.20 for facilities accepting non-MSW Subtitle D wastes overestimate DOC at these landfills and may result in inaccurate estimates of landfill gas generation and methane emissions.[7]

Based on this review of the DOC values for MSW landfills, the waste sector concludes that the long-standing DOC values developed in the past over-estimate both landfill gas generation and methane emissions. The data provided by EREF confirms that two trends are driving the changes in waste composition at MSW Landfills. First, many MSW Landfills are handling less organic matter now, and we anticipate this trend will continue due to state and local organics diversion goals. Second, the increase of Subtitle D non-MSW waste disposed has altered the DOC for all waste deposited in MSW Landfills. EPA validates these trends in the Inventory's Chapter 6 discussion of carbon sequestration of harvested wood products, yard waste and food waste, which shows a significant reduction in sequestered carbon since 1990 due to reduced volumes of organic wastes disposed in landfills.

Based on EREF's research, we urge EPA to update the DOC values to reflect significant changes in the amounts and types of organic materials being landfilled over the past 20 years. The values now in use are inaccurate and should not be used going forward. We recommend that EPA review and update the DOC values for the entire time series for the 2019 version of the GHG Inventory, and prioritize updates of the DOC values used in calculating GHG emissions under Subpart HH of the GHGRP.

Further, as EPA clearly recognizes that the composition of the waste at MSW Landfills has changed and continues to change, we suggest the Agency add an additional factor, "(5) the composition of the waste" to the sentence on line 42, page 7-2 of the waste chapter that begins: "Methane generation and emissions from landfills are a function of several factors."

[2] The Environmental Research & Education Foundation (2019). Analysis of Waste Streams Entering MSW Landfills: Estimating DOE Values and the Impact of Non-MSW Materials. Retrieved from www.erefdn.org. pp. 8 - 9.
[3] Ibid., p. 10.
[4] Ibid., p. 11.
[5] Ibid., p. 13.
[6] Ibid., p. 14.
[7] Ibid., p. 15.

Response: As stated in the Planned Improvements section of Section 7.1 of the U.S. Greenhouse Gas Inventory of Emissions and Sinks, EPA is developing a multivariate analysis solving for optimized DOC and k- across the more than 1,100 landfills that report under subpart HH of the GHGRP. This analysis uses publicly available data directly reported to the GHGRP. The results of this analysis could inform updates to the default DOC and k-values used by landfills subject to reporting under subpart HH of the GHGRP in calculating their facility level emissions. For updates to the DOC to be reflected in the Inventory, the updates also need to be incorporated in Subpart HH of the GHGRP given its direct use in estimating national-level emissions from MSW landfills.

With regard to the suggested text edit, EPA has already reflected the importance of waste composition with the sentence that begins "Methane generation and emissions from landfills are a function of several factors, including (1) the total amount and composition of waste-in-place…."

Comment 38: The k factor (Methane generation rate constant)

Our previous years' comments on k factors remain unchanged and are repeated below. The waste sector strongly supports EPA's plans to review these k values against new data and other landfill gas models, as well as assess the uncertainty factor applied to these k values in the Waste Model. We have been concerned that these k-values are outdated and rife with uncertainty, as confirmed by the *Draft AP 42.2.4 Municipal Solid Waste Landfills*, which states:

> There is a significant level of uncertainty in Equation 2 and its recommended default values for k and L_o. The recommended defaults k and L_o for conventional landfills, based upon the best fit to 40 different landfills, yielded predicted CH_4 emissions that ranged from ~30 to 400% of measured values and had a relative standard deviation of 0.73 (Table 2-2). The default values for wet landfills were based on a more limited set of data and are expected to contain even greater uncertainty.[8]

The waste sector has previously highlighted the significant issues with the k values used in the Draft AP-42 Section 2.4: Municipal Solid Waste Landfills. In fact, EPA has never finalized AP-42 for MSW landfills, despite the k-value issues identified *by EPA* in both AP-42 and the Background Information Document. With uncertainties in CH_4 emissions ranging from -30% to 400% under EPA's assessment of the LandGEM model, it is difficult to rely on these data. For this reason, we support EPA's plan to review and resolve the significant problems in the k value data set. However, we also suggest review L_0 value. Although an independent variable, L_0 should be considered in conjunction with k value modifications because it is related to fitting the curve, where the results will be dependent on the assumptions used for the L_0/DOC.

[8] U.S. EPA, *Draft AP 42.2.4: Municipal Solid Waste Landfills*, October 2008, p. 2.4-6.

Response: As stated in the Planned Improvements section of Section 7.1 of the U.S. Greenhouse Gas Inventory of Emissions and Sinks, EPA is developing a multivariate analysis solving for optimized DOC and k-values across the more than 1,100 landfills that report under subpart HH of the GHGRP. This analysis uses publicly available data directly reported to the GHGRP. The results of this analysis could inform updates to the default DOC and k-values used by landfills subject to reporting under Subpart HH of the GHGRP in calculating their facility level emissions. As the commenter already acknowledged for updating DOC, for updates to the k-value to be reflected in the Inventory, the updates also need to be incorporated in Subpart HH of the GHGRP given its direct use in estimating national-level emissions from MSW landfills.

Composting Specific

Comment 39: Datasets on industrial composting facilities

The waste sector does not have datasets on industrial composting facilities located in U.S. territories.

Response: EPA appreciates the commenter's feedback on the current lack of datasets on composting facilities in U.S. territories.

Comment 40: Compost emission factor

Our previous years' comments on compost emission factor remain unchanged and are repeated below. In ideal conditions, the composting process occurs at a moisture content of between 50 and 60%, but the moisture content of feedstocks received at composting sites varies and can range from 20% to 80%. It is common for moisture to be added to dry feedstocks prior to the start of composting to optimize the biological process. In the calculation of emissions from composting in the draft chapter, it appears that all incoming wastes were assumed to have a moisture content of

60%. If 60% is not reflective of the actual weighted average of all feedstocks, this will introduce errors in the inventory calculation that could be significant.

We recommend that the calculations be based on waste subcategories (i.e., leaves, grass and garden debris, food waste) and category-specific moisture contents, or ask that further information be provided on the rationale for assuming 60% as the average moisture content of all inbound materials.

Response: EPA notes the commenter's feedback on the moisture content levels used in the calculation of emissions from composting. The calculations for composting are based on IPCC Tier 1 methodology defaults. Under this methodology, the emission factors for CH_4 and N_2O assume a moisture content of 60% in the wet waste. (IPCC 2006) EPA has included this detail to the Methodology section of Section 7.3 of the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018, as was done in the previous year's inventory report, so that the source of the moisture content is more transparent. In addition, EPA continues to include in the Planned Improvements section of Section 7.3 that EPA is looking into the possibility of incorporating more specific waste subcategories and category-specific moisture contents into the emissions estimates for composting in the United Stated to improve accuracy. However, to date the EPA has not been able to locate substantial information on the composition of waste at U.S. composting facilities to do so. As additional data becomes available on the composition of waste at these facilities, EPA will consider using this information to create a more detailed calculation of U.S. composting emissions.

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: 1990-2018* to a list of ~220 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.

- April Leytem - United States Department of Agriculture (USDA)
- Anne Germain - Waste Management, Republic Services, National Waste & Recycling Association, Solid Waste Association of North America, SCS Engineers, and Weaver Consulting Group
- Barry Malmberg - National Council for Air and Stream Improvement (NCASI), Inc.
- David Lax- American Petroleum Institute (API)
- Jesse Maxwell - Waste Management, Republic Services, National Waste & Recycling Association Solid Waste Association of North America, SCS Engineers, and Weaver Consulting Group
- Jeremy Martin – Union of Concerned Scientists (UCS)
- John Davies – United States Department of Transportation (USDOT)
- Stephen Jasinski – National Minerals Information Center United States Geological Survey (USGS)

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

Appendix B: Dates of review

- Energy: October 17 - November 15, 2019
- Industrial Processes and Product Use (IPPU): October 17-November 15, 2019
- Waste: October 17 - November 15, 2019
- Agriculture: October 28 – November 25, 2019
- Land Use, Land Use Change and Forestry (LULUCF): November 13 – December 13, 2019

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: 1990-2018* 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 1990-2018 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 to improve the completeness and/or accuracy of the Energy chapter.

Source-Specific Questions:

Fossil Fuel Combustion: CO2 from Fossil Fuel Combustion

1. Please provide your overall impressions of the clarity of the discussion of trends in CO2 emissions from fossil fuel combustion. Please provide recommendations for any information that could be added to the discussion to provide additional transparency and clarity.
2. Data for energy use in U.S. Territories comes from the International Energy Statistics provided by EIA. This source has data only through 2014; the years 2015 through 2018 are proxies. Are there 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: CH4 and N2O from Stationary Combustion

1. The CH4 and N2O emission factors for the electric power sector are based on a Tier 2 methodology, whereas all other sectors utilize a Tier 1 methodology. For all other stationary sectors, the emission factors used in Tier 1 methods are primarily taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Are there other more U.S.-specific CH4 and N2O emission factor data sources that could be utilized, especially for natural gas combustion sources?

Carbon Emitted from Non-Energy Uses of Fossil Fuels

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

Gasoline Carbon Factor

Gasoline Component Composition:

1. Is the EPA Trends data a good data source for determining gasoline composition? Are there other sources available, including for the full time series 1990-2018 and going forward?
2. Is it reasonable to apply the EPA Trends data across all fuel types (i.e., California fuels not included)?
3. Should the EPA Trends data be used for the full time series or just for years where the NIPER data is not available?
4. If using across the time series, is it reasonable to apply the 1997 results to 1990-1996 and the 2016 results to 2017-2018?

Component Speciation:

1. Is it reasonable to use the API data to speciate gasoline components?
2. Is the approach outlined in Annex 2 of this memo to develop the gasoline speciated components reasonable (see p. 15)?
3. Is the API data representative of different gasoline types? If not, is there a better approach to use?
4. Is the API data representative over time? If not is there a better approach?
5. Are there other gasoline speciation data available?
6. Would it be better to use a representative molecule to represent carbon content of different gasoline components?

Carbon Factor:

1. The carbon factor of each gasoline component is based on a percent by mass and are distributed across the full fuel based on the density of the entire gallon. Should individual densities be used instead? If so is there a good source of data for these densities?
2. The carbon factors are lower than what was found previously; do the updated values seem reasonable?

Heating Value:

1. Is the approach for developing heating values reasonable?
2. Are there other data sources available on heating content?
3. The factor is slightly higher than current factors used; do the update seem reasonable?

See also attached at the end of Appendix C two additional technical memo outlining proposed improvements to emission factors for On-Highway CH_4 and N_2O and Emission Factors Gasoline CO_2 Emission Factors.

Industrial Processes and Product Use (IPPU)

Requests for Expert Feedback for the 1990-2018 IPPU Chapter

General Questions:

1. Please provide your overall impressions of the transparency of the IPPU chapter.
2. Please provide any recommendations that EPA can consider to improve the completeness and/or accuracy of the IPPU chapter.
3. 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. **Other process uses of carbonates -** Please provide information on:
    - Data on carbonate use in non-metallurgical magnesium production.
    - Data on carbonate use in the production of ceramics.

Chemicals

2. **Caprolactam, Glyoxal and Glyoxylic Acid Production** - With the inclusion of this new IPPU source category as of the last Inventory, EPA requests feedback on the overall chapter text, assumptions and information on the state of the industry.
3. **Calcium Carbide Production** - Please provide input on data sources and industry information on production to estimate emissions using IPCC methods.
4. **Phosphoric Acid Production**: Please provide input on data sources and assumptions regarding phosphate rock including:
    - Regional production data and the assumption that 2018 regional production was estimated based on regional production data from 2005 to 2011.
    - 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

5. **Zinc Production**: The EPA seeks comments on assumptions applied 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?
6. **Iron and Steel Production**: The EPA seeks data on carbonaceous material (other than coking coal) consumption and coke oven gas production from merchant coke plants.

Other IPPU Categories

7. **ODS Substitutes -** The EPA seeks comments 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).

Agriculture

Request for Expert Feedback for the 1990-2018 Agriculture Chapter

General Questions:

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

Source-Specific Questions:

4. 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?
5. 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?

6. 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:
    a. Waste management system data, particularly seasonal changes in emissions from different WMS;
    b. Maximum methane producing capacity;
    c. Volatile solids and nitrogen excretion rates;
    d. Measured emission estimates (by waste management system) to help refine estimates of methane conversion factors.
7. 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?
8. 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:
    a. Dry matter/gross energy intake;
    b. Annual data for the DE, Y_m, and crude protein values of specific diet and feed components for foraging and feedlot animals;
    c. Monthly beef births and beef cow lactation rates;
    d. Weights and weight gains for beef and dairy cattle.
9. 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)

Request for Expert Feedback for the 1990-2018 LULUCF Chapter

General Questions:

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

Category-Specific Questions

4. For the Yard Trimmings and Food Scraps category, is the state of the industry current and accurately described? Are there other technologies, practices, trends that we should consider?
5. For the Yard Trimmings and Food Scraps category, are there other data sources that EPA should be aware of and consider in the calculating these emissions? Especially for:
    - C storage, decay rates, etc. for yard trimmings and food scraps
    - Decay rates of food scraps, leaves, grass, and branches
    - National yard waste compositions
    - Precipitation range percentages for populations for the decay rate sensitivity analysis

Waste

Request for Expert Feedback for the 1990-2018 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.

Wastewater Specific Questions:

1. The wastewater source category relies on national production data from a variety of sources for calculating emissions estimates. Are there other data sources that EPA should be aware of and consider in the emissions calculations of this source?

2. Please provide input on any additional sources of wastewater outflow or BOD production that we may consider in our industrial methane emissions calculations. Do our estimates of the type of wastewater treatment systems in use seem reasonable?

3. 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. National level data on the biogas generation and recovery operations,
    d. The estimates of the percent of BOD removed by aerobic, anaerobic, and other treatment systems for our methane estimates,
    e. 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? and
    f. 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).

4. Are there additional industries that are sources of methane or nitrous oxide emissions that should be included in the wastewater inventory? Are there available sources of national-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?

6. Is the state of domestic and industrial wastewater treatment current and accurately described?

7. As stated in our Planned Improvements, EPA will be incorporating refinements to next year's Inventory 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 you would like to bring to our attention, or other refinements that should be included?

Landfill-Specific Questions

1. 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.

2. A comprehensive Internet search by state was conducted to identify waste characterization studies published as of July 2018. We plan to conduct analyses to generate DOC values specific to the time frame of 1990 to 2004. This time frame is specified because the Inventory uses directly reported GHGRP net emissions, which incorporate the DOC values allowed under the rule, in years beyond 2004. Please comment and provide information on any additional studies that have not been published on the Internet from 1990 to date that may further these efforts.

3. An analysis is being conducted on decay rate values reported by select UNFCCC Annex 1 countries (e.g. Australia, Czech Republic, France, Germany, Italy, Norway, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom) in their annual National Inventory Reports (NIR), as well as decay rate values used as defaults in first order decay models not used for NIR estimation, as compared to the U.S. Greenhouse Gas Inventory defaults used in the U.S. Waste model. This analysis is specific to the 1990 to 2004 time frame, because the Inventory uses directly reported GHGRP net emissions, which incorporate the decay rate values allowed under the rule, for years beyond 2004. Please comment and provide information on any additional studies and models, other than the ones listed below, that have not been published on the Internet from 1990 to date if any stakeholders have this information available to share.
    - LandGEM: (EPA 2005) Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide. EPA-600/R-05/047.
    - MSW DST: (NCSU and RTI 2000) Default Data and Data Input Requirements for the Municipal Solid Waste Management Decision Support Tool.
    - WARM: (EPA) Waste Reduction Model (WARM) Tool User's Guide. Version 14 (March 2016).
    - E-PRTR: (ADEME 2003) Outil de calcul des emissions dans l'air de CH4, CO2, SOx, NOx issues des centres de stockage de dechets menagers et assimiles Available at: https://www.declarationpollution.ecologie.gouv.fr/gerep/download/Annexe_2_Outil_de_calcul_ADEME_des_emissions_dans_lair_CH4_CO2_NOX_SO.pdf_
    - MELMod: (Gregory et al. 2004) Review of Landfill Methane Emissions Modelling (MELMod). Submitted to the Department of the Environment, Food, and Rural Affairs.
    - GasSim: (GasSim 2.5 User Manual. 2018)

4. Additional information regarding the scale-up factor methodology used within the latter portion of the Landfills sector time series has been added to the Inventory Annex specific to landfill sin response to comments submitted by the UNFCCC. Please comment on the clarity of the more detailed scale-up factor methodology and its explanation and provide information on any portion of the approach that is unclear.

Composting-Specific Questions

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.

Appendix D: Supplemental Technical Memos to Expert Reviewers for Energy Sector

1) On-Highway CH_4 and N_2O Emission Factors Update Memo
2) Gasoline C Factor Update Memo

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2018:
Updated On-Highway CH_4 and N_2O Emission Factors

This memo provides research and analyses to support improvements to the transportation and mobile source component of the Inventory of U.S. Greenhouse Gas Emissions and Sinks. Improved on-highway gasoline and diesel vehicle methane (CH_4) and nitrous oxide (N_2O) emissions factors are estimated.

Summary

This memo details proposed updates to the on-highway CH_4 and N_2O emission factors used in the mobile source component of the U.S. Greenhouse Gas Inventory.

- **Current Method –** N_2O emission factors for gasoline and diesel Tier 2, Tier 3, LEV II and LEV III light-duty vehicles (LDV), light-duty trucks (LDT) and heavy-duty vehicles (HDV) are derived from a regression analysis done by EPA. CH_4 emission factors are calculated based on the ratio of NMOG emission standards.
- **Proposed Method –** Updated CH_4 and N_2O emission factors are derived from annual certification data for vehicles[1], to demonstrate compliance with federal vehicle emissions regulations.

Background

On-highway CH_4 and N_2O emission factors were last revised in 2017, based upon a regression analysis done by EPA for N_2O and the ratio of NMOG emission standards for CH_4.[2] Emission factors were developed for gasoline LDVs, LDTs and HDVs for Federal emission standard Tier 2, California emission standards LEV and, LEV II, and combined emission factors for the new Federal (Tier 3) and California (LEV III) emission standards. Federal and California emission standards are shown in Appendix A. Since that time, data from manufacturer testing of vehicles to meet certification standards have been published by EPA, providing sufficient data to update the emission factors for both gasoline and diesel on-highway vehicles.[3] Development of emission factors using these data will help improve the accuracy of the GHG inventory.

Assumptions

Tier 2, Tier 3, LEV II and LEV III emission standards (see Appendix A) include several emission bins to which manufacturers can certify vehicles, to meet a corporate average emission level which decreases over time. The proposed CH_4 and N_2O emission factors do not currently distinguish between emission bins but provide overall emission factors for each emission standard set. Data are not available to determine CH_4 and N_2O emission factors by emission bin.

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

[2] ICF, *Updated On-Highway CH_4 and N_2O Emission Factors for GHG Inventory,* Prepared for U.S. Environmental Protection Agency, October 2017.

[3] EPA, Certification and fuel economy data for passenger cars and trucks, available at https://www.epa.gov/sites/production/files/2019-02/light-duty-vehicle-test-results-report-2014-present.xlsx and https://www.epa.gov/sites/production/files/2019-02/heavy-duty-gas-and-diesel-engines-2015-present.xlsx

Calculations

Vehicle class is first determined from the Vehicle Class Description field in the compliance data. Average emission factors by vehicle class for gasoline vehicles are pulled directly from the compliance data. Table 1 compares the updated (new) emission factors against the emission factors currently used in the Inventory.

Table 1. Current and Proposed (New) CH_4 and N_2O Emission Factors for Onroad Gasoline Vehicles (g/mi)

Class	Standard	CH_4		N_2O	
		Current	New	Current	New
LDGV	Tier 2	0.008	0.007	0.008	0.005
	Tier 3	0.002	0.006	0.007	0.001
	LEV II	0.006	0.007	0.008	0.004
	LEV III	0.002	0.005	0.007	0.001
LDGT	Tier 2	0.008	0.010	0.008	0.003
	Tier 3	0.002	0.009	0.007	0.001
	LEV II	0.006	0.008	0.008	0.006
	LEV III	0.002	0.007	0.007	0.001
HDGV	Tier 2	0.008	0.030	0.017	0.002
	Tier 3	0.011	0.025	0.016	0.006
	LEV II	0.021	0.039	0.008	0.005
	LEV III	0.011	0.041	0.016	0.014

New average emission factors for aftertreatment (AF) diesel vehicles (Table 2) are also derived from EPA compliance data, in the same manner as described above.

Table 2. Current and Proposed (New) CH_4 and N_2O Emission Factors for Onroad Diesel Vehicles (g/mi)

Class	CH_4		N_2O	
	Current	New	Current	New
LDDV	0.000	0.030	0.001	0.019
LDDT	0.001	0.029	0.001	0.021
HDDV	0.005	0.009	0.005	0.043

Table 1 shows that the proposed (new) emission factors for gasoline cars and trucks are generally lower than what is currently used in the Inventory. Emission factors for diesel cars and trucks with aftertreatment control technology (Table 2) are significantly higher than current values, due to the use of SCR technology on diesel vehicles to achieve lower NOx emissions.

Impacts of the new emission factors are shown in Table 3 in 1000 metric tonnes of emissions for the entire on-highway inventory for calendar years 2016 and 2017.

Table 3. Emission Inventory Impact of Current vs. Proposed (New) CH_4 and N_2O Emission Factors in 1000 Metric Tonnes

Class	CY 2016				CY 2017			
	CH_4		N_2O		CH_4		N_2O	
	Current	New	Current	New	New	Current	New	Current
LDGV	23.32	23.47	29.90	23.71	21.33	19.19	27.44	20.36
LDGT	8.10	9.24	11.62	9.20	7.26	5.98	10.29	7.68
HDGV	1.41	1.13	1.41	1.14	1.24	1.34	1.31	1.10
LDDV	0.01	0.27	0.01	0.17	0.00	0.28	0.01	0.18
LDDT	0.02	0.51	0.04	0.38	0.02	0.55	0.04	0.41
HDDV	1.33	2.40	1.25	10.75	1.38	2.51	1.30	11.25
Total	**34.19**	**37.02**	**44.22**	**45.36**	**31.24**	**29.85**	**40.38**	**40.98**

As shown in Table 3, the new emission factors result in higher CH_4 and N_2O emissions in CY2016 for most vehicle classes, resulting in greater total CH_4 and N_20 emissions in that year. In CY2017, the updated emission factors result in lower total CH_4 emissions, while total N_2O emissions increase slightly. Much of the increase in N_2O emissions is due to the increase of aftertreatment emission factors for diesel vehicles.

Federal and California Light-Duty Vehicle Emissions Standards for Air Pollutants

Tier 3 and LEV III Program

Standard[1]		MY Fully Implemented Tier/LEV	Vehicles	Emission Limits at Full Useful Life[2] Maximum Allowed Grams Per Mile				
				NOx + NMOG	CO	PM (Tier/LEV)[3]		HCHO
Bin 0	N/A[4]	2025/2015	LDV, LDT, MDPV	0	0	0	0	0
Bin 20	SULEV20	2025/2015	LDV, LDT, MDPV	0.02	1	0.003	0.01	0.004
Bin 30	SULEV30	2025/2015	LDV, LDT, MDPV	0.03	1	0.003	0.01	0.004
Bin 50	ULEV50	2025/2015	LDV, LDT, MDPV	0.05	1.7	0.003	0.01	0.004
Bin 70	ULEV70	2025/2015	LDV, LDT, MDPV	0.07	1.7	0.003	0.01	0.004
Bin 125	ULEV125	2025/2015	LDV, LDT, MDPV	0.125	2.1	0.003	0.01	0.004
Bin 160	LEV160	2025/2015	LDV, LDT, MDPV	0.16	4.2	0.003	0.01	0.004

Tier 3 Final Rule LEV III Final Order CARB ZEV Program

Tier 2 Program[5,6]

Standard	MY	Vehicles	NOx + NMOG	CO	PM	HCHO
Bin 1	2004+	LDV, LLDT, HLDT, MDPV	0	0	0	0
Bin 2	2004+	LDV, LLDT, HLDT, MDPV	0.03	2.1	0.01	0.004
Bin 3	2004+	LDV, LLDT, HLDT, MDPV	0.085	2.1	0.01	0.011
Bin 4	2004+	LDV, LLDT, HLDT, MDPV	0.11	2.1	0.01	0.011
Bin 5	2004+	LDV, LLDT, HLDT, MDPV	0.16	4.2	0.01	0.018
Bin 6	2004+	LDV, LLDT, HLDT, MDPV	0.19	4.2	0.01	0.018
Bin 7	2004+	LDV, LLDT, HLDT, MDPV	0.24	4.2	0.02	0.018
Bin 8a	2004+	LDV, LLDT, HLDT, MDPV	0.325	4.2	0.02	0.018
Bin 8b	2004-2008	HLDT, MDPV	0.356	4.2	0.02	0.018
Bin 9a	2004-2006	LDV, LLDT	0.39	4.2	0.06	0.018
Bin 9b	2004-2006	LDT2	0.43	4.2	0.06	0.018
Bin 9c	2004-2008	HLDT, MDPV	0.48	4.2	0.06	0.018
Bin 10a	2004-2006	LDV, LLDT	0.756	4.2	0.08	0.018
Bin 10b	2004-2008	HLDT, MDPV	0.83	6.4	0.08	0.027
Bin 10c	2004-2008	LDT4 ,MDPV	0.88	6.4	0.08	0.027
Bin 11	2004-2008	MDPV	1.18	7.3	0.12	0.032

Tier 2 Rule

EPA United States Environmental Protection Agency

EPA-420-F-16-002
February 2016

Appendix A
Federal and California Light Duty Vehicle Emission Standards for Air Pollutants

Federal and California Light-Duty Vehicle Emissions Standards for Air Pollutants

LEV II Program

Standard	MY	Vehicles	NOx + NMOG	CO	PM	HCHO
ZEV	2004+	LDV, LDT	0	0	0	0
PZEV *	2004+	LDV, LDT	0.03	1	0.01	0.004
SULEV II	2004+	LDV, LDT	0.03	1	0.01	0.004
ULEV II	2004+	LDV, LDT	0.125	2.1	0.01	0.011
LEV II	2004+	LDV, LDT	0.16	4.2	0.01	0.018
LEV II Option 1	2004+	LDV, LDT	0.19	4.2	0.01	0.018
SULEV II	2004+	MDV4	0.2	3.2	0.06	0.008
ULEV II	2004+	MDV4	0.343	6.4	0.06	0.016
LEV II	2004+	MDV4	0.395	6.4	0.12	0.032
SULEV II	2004+	MDV5	0.317	3.7	0.06	--
ULEV II	2004+	MDV5	0.567	7.3	0.06	--
LEV II	2004+	MDV5	0.63	7.3	0.12	--

LEV II Rule

Tier 1 Program

LDV	1994 2003	LDV	0.91	4.2	0.01	--
LDT1	1994 2003	LDT1	0.91	4.2	0.01	0.8
LDV diesel	1994 2003	LDV	1.56	4.2	0.01	--
LDT1 diesel	1994 2003	LDT1	1.56	4.2	0.01	0.8
LDT2	1994 2003	LDT2	1.37	5.5	0.01	0.8
LDT3	1994 2003	LDT3	1.44	6.4	0.01	0.8
LDT4	1994 2003	LDT4	2.09	7.3	0.12	0.8

Tier 1 Rule

Appendix A
Federal and California Light Duty Vehicle Emission Standards for Air Pollutants

Federal and California Light-Duty Vehicle Emissions Standards for Air Pollutants

LEV I Program

Standard	MY	Vehicles	NOx + NMOG	CO	PM	HCHO
ULEV I diesel	2001-2006	LDV, LDT1	0.355	2.1	0.04	0.011
ULEV I	2001-2006	LDV, LDT1	0.355	2.1	n/a	0.011
SULEV I	2001-2006	MDV2	0.372	3.2	0.05	0.006
LEV I diesel	2001-2006	LDV, LDT1	0.39	4.2	0.08	0.018
LEV I	2001-2006	LDV, LDT1	0.39	4.2	n/a	0.018
ILEV		LDV, LDT1	0.39	4.2	0.08	--
ULEV I	2001-2006	MDV2	0.407	2.5	0.04	0.012
LEV I	2001-2006	LDV, LDT1	.456/.61	4.2	0.08	--
SULEV I	2001-2006	MDV3	0.534	3.7	0.06	0.008
ULEV I diesel	2001-2006	MDV2	0.57	2.8	0.05	0.013
ULEV I	2001-2006	MDV2	0.57	2.8	n/a	0.013
SULEV I	2001-2006	MDV4	0.6	4.1	0.06	0.01
ILEV		LDT2	0.63	5.5	0.08	--
LEV I diesel	2001-2006	LDT2	0.63	5.5	0.1	0.023
LEV I	2001-2006	LDT2	0.63	5.5	n/a	0.023
ULEV I	2001-2006	MDV2	0.743	6.4	0.05	0.013
TLEV I diesel	2001-2003	LDV, LDT1	0.756	4.2	0.08	0.018
TLEV I	2001-2003	LDV, LDT1	0.756	4.2	n/a	0.018
LEV I	2001-2006	MDV2	0.83	6.4	0.1	0.027
SULEV I	2001-2006	MDV5	0.83	5.2	0.06	0.013
ULEV I	2001-2006	MDV3	1.067	7.3	0.06	0.016
TLEV I diesel	2001-2006	LDT2	1.1	5.5	0.1	0.023
TLEV I	2001-2006	LDT2	1.1	5.5	n/a	0.023
LEV I	2001-2006	MDV3	1.18	7.3	0.12	0.032
ULEV I	2001-2006	MDV4	1.197	8.1	0.06	0.021
LEV I	2001-2006	MDV4	1.33	8.1	0.12	0.04
ULEV I	2001-2006	MDV5	1.697	10.3	0.06	0.026
LEV I	2001-2006	MDV5	1.93	10.3	0.12	0.052

[1]Doesn't Include Tier 3 transitional bins (Bin 85 and Bin 110)
[2]Tier and LEV III are certified to 150,000 mi life, not 100-120,000 as in previous programs
[3]Starting in 2017, LEV PM standards drop to 0.003g/mi, with 100% certifying by 2021, and drop further starting in 2025
[4]ZEVs are handled separately under CARB's ZEV Program
[5]Prior to Tier 3 and LEVIII, NOx and NMOG had separate standards, but are shown here as combined for easier comparison
[6]Doesn't include federal NLEV standards which applied MY 1999 to 2003 LDV and LLDT vehicles

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2018:
Updated Gasoline CO_2 Emission Factors

This memo provides research and analyses to support improvements in the U.S. Greenhouse Gas Inventory. Updated gasoline carbon factors are estimated.

Summary

This memo details suggested changes to the gasoline 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 reports are out of circulation. Current C factors have not been updated since 2010 (for the 1990-2008 Inventory Report).
- **Proposed Method –** New data are available in publications after 2009, including historic data, which can be used to calculate new gasoline carbon factors. It is proposed to use this data to develop gasoline carbon factors for years after 2008 and update carbon factors from 1990 to 2008.
- **Charge Questions –** There are charge questions related to the proposed method provided at the end of the memo to help focus the review (see p.12)

Background

The current GHG inventory calculates grams of carbon dioxide (CO_2) emitted from gasoline 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 gasoline energy use. This latter factor provides million metric tonnes (MMT) of carbon (C) per QBtu of gasoline and is based upon the density, higher heating value and carbon content 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 C.

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. Since that time the C factor has not been updated to reflect current gasolines properties.

The proposed updated approach described here relies on a number of new data sources. The Energy Information Administration (EIA) publishes prime supplier sales volumes of motor gasoline by type (conventional, oxygenated, and reformulated) and by grade (regular, midgrade

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

and premium) for each month from 1983 to present.[2] EPA publishes a breakdown of conventional and reformulated gasoline in their Trends report[3] which gives volumes of gasoline components (aromatics, benzene, oxygenates and olefins) by gasoline type (conventional and reformulated) and season (winter and summer), for fuels sold outside of California, for 1997-2016. Finally, the American Petroleum Institute (API) provided sample non-oxygenated compositions of both winter and summer gasolines[4] that can be used to determine C contents of different gasoline components. The combination of these sources was used to determine an updated C factor for gasoline over the time series of the Inventory.

Assumptions

The EPA Trends report is assumed to provide a representative mix of components in the different types of gasoline sold. The breakdown of compounds within the saturated, aromatic and olefin components in the API data are assumed to be similar enough to the gasolines being produced over time and across grades. These assumptions are discussed below and further outlined as part of Charge Questions at the end of this memo.

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 separately in the inventory. Total volumes of non-ethanol gasoline sales are shown in Table 1.

Table 1. Non-Ethanol Gasoline Sales in 1000 bbls

Calendar Year	Conventional		Oxygenated		Reformulated	
	Winter	Summer	Winter	Summer	Winter	Summer
1990	1,587,068	1,035,872	0	0	0	0
1991	1,589,226	1,013,590	0	0	0	0
1992	1,627,363	1,009,097	0	0	0	0
1993	1,658,914	1,042,531	0	0	0	0
1994	1,344,579	1,049,013	266,828	11,522	71,868	0
1995	1,145,737	800,856	114,774	11,405	451,519	285,645
1996	1,157,119	751,545	77,268	14,110	518,768	345,532
1997	1,138,680	748,390	62,703	19,205	568,670	358,602
1998	1,145,856	753,870	74,768	29,868	596,512	378,586
1999	1,180,808	766,023	77,526	29,788	605,392	383,353
2000	1,157,251	768,017	79,075	35,245	627,127	394,692
2001	1,173,842	776,007	79,489	34,018	639,032	398,828
2002	1,200,769	794,617	78,780	35,323	658,380	412,230

[2] EIA, *Prime Supplier Sales Volume* at https://www.eia.gov/dnav/pet/pet_cons_prim_dcu_nus_m.htm

[3] EPA, *Gasoline Properties Over Time* at https://www.epa.gov/fuels-registration-reporting-and-compliance-help/gasoline-properties-over-time

[4] https://www.api.org/~/media/Files/Policy/Fuels-and-Renewables/2016-Oct-RFS/The-Truth-About-E15/E10-Blending-Study-Final-Report.pdf

Calendar Year	Conventional		Oxygenated		Reformulated	
	Winter	Summer	Winter	Summer	Winter	Summer
2003	1,205,428	799,970	78,803	37,278	655,751	416,721
2004	1,254,363	813,280	74,362	33,279	664,195	408,525
2005	1,237,444	809,139	71,579	35,752	668,202	424,381
2006	1,285,904	834,180	71,823	35,189	641,003	378,570
2007	1,352,219	861,717	0	0	623,224	388,163
2008	1,271,936	781,475	0	0	627,781	378,309
2009	1,224,432	787,366	0	0	622,290	386,866
2010	1,198,796	772,241	0	0	615,419	389,707
2011	1,161,169	733,142	0	0	615,060	378,399
2012	1,160,682	735,152	0	0	600,701	374,440
2013	1,179,391	744,877	0	0	606,171	382,592
2014	1,191,305	752,585	0	0	612,322	379,800
2015	1,209,040	769,418	0	0	639,065	400,519
2016	1,226,520	781,341	0	0	651,325	409,047
2017	1,237,358	795,119	0	0	628,616	398,210
2018	1,238,651	798,821	0	0	627,931	393,685

Next, the density of non-ethanol conventional and reformulated gasoline is calculated from the EPA Trends data. Gasoline density (including ethanol) is calculated based on API gravity using the following formula:

$$\rho_g = 141.5 / (API + 131.5) \times \rho_w$$

Where:

ρ_g = density of gasoline (kg/gallon)

API = API gravity (annual data from the EPA Trends report as shown in Annex 1)

ρ_w = density of water, 3.785 kg/gallon

Finally the ethanol component is removed and density adjusted using the following formula:

$$P_{neg} = (\rho_g - EV \times \rho_e) / (1-EV)$$

Where:

ρ_{neg} = density of non-ethanol gasoline (kg/gallon)

ρ_g = density of gasoline (kg/gallon)

EV = ethanol volume percent

ρ_e = density of ethanol, 2.988 kg/gallon

This provides the densities shown in Table 2.

Table 2. Non-Ethanol Gasoline Densities (kg/gallon)

Calendar Year	Non-Ethanol Gasoline Densities			
	Conventional		Reformulated	
	Winter	Summer	Winter	Summer
1997	2.778	2.823	2.758	2.825
1998	2.774	2.824	2.766	2.826
1999	2.775	2.822	2.766	2.823
2000	2.774	2.830	2.760	2.811

Calendar Year	Non-Ethanol Gasoline Densities			
	Conventional		Reformulated	
	Winter	Summer	Winter	Summer
2001	2.783	2.833	2.763	2.817
2002	2.780	2.830	2.762	2.817
2003	2.784	2.836	2.763	2.815
2004	2.767	2.823	2.762	2.818
2005	2.765	2.818	2.763	2.815
2006	2.767	2.823	2.763	2.816
2007	2.762	2.821	2.756	2.806
2008	2.753	2.801	2.746	2.795
2009	2.755	2.806	2.749	2.805
2010	2.751	2.798	2.749	2.801
2011	2.748	2.792	2.738	2.800
2012	2.741	2.787	2.735	2.790
2013	2.737	2.784	2.729	2.787
2014	2.735	2.781	2.724	2.783
2015	2.778	2.823	2.758	2.825
2016	2.774	2.824	2.766	2.826

Quantities sold of non-ethanol conventional and reformulated gasoline are then divided into components (MTBE, TAME, Benzene, non-Benzene Aromatics, Olefins and Saturates) using the EPA Trends report (see Annex 1). Winter and summer grades of conventional gasoline are shown in Tables 3 and 4, respectively and winter and summer grades of reformulated gasoline are shown in Tables 5 and 6, respectively. Note that the EPA Trends report only provides gasoline component breakdowns for 1997 through 2016.

Table 3. Winter Grade Conventional Gasoline Sales

Calendar Year	Volume (1000 bbls)					
	MTBE	TAME	Aromatics*	Benzene	Olefins	Saturates
1997	6,780	295	234,355	11,300	119,880	609,715
1998	21,672	2,530	259,848	11,881	123,213	672,063
1999	20,139	1,245	269,495	12,219	128,977	688,106
2000	15,984	1,725	272,763	12,419	137,991	695,362
2001	17,994	2,220	283,467	13,320	146,057	690,906
2002	16,337	3,196	283,286	12,667	139,690	714,429
2003	17,138	2,057	271,915	12,568	131,388	690,527
2004	21,125	2,158	267,126	12,266	129,474	681,556
2005	16,058	2,050	268,201	13,097	132,107	682,403
2006	2,037	113	266,315	13,242	125,631	719,039
2007	339	0	261,386	12,985	125,330	714,266
2008	103	0	222,640	12,043	107,048	646,921
2009	0	0	218,490	11,610	102,394	647,415
2010	0	0	213,749	10,351	100,738	653,945
2011	0	0	226,292	8,451	107,864	732,398
2012	0	0	209,780	7,428	99,038	709,920
2013	0	0	208,149	6,938	101,993	734,533
2014	0	0	208,951	7,001	102,874	760,102
2015	0	0	212,584	7,042	99,190	764,036
2016	0	0	216,744	6,900	96,595	756,345

Table 4. Summer Grade Conventional Gasoline Sales

Calendar Year	Volume (1000 bbls)					
	MTBE	TAME	Aromatics*	Benzene	Olefins	Saturates
1997	9,949	553	240,154	10,409	115,149	544,055
1998	17,768	2,140	244,293	10,605	106,983	543,008
1999	16,817	1,208	245,746	10,685	109,633	537,203
2000	14,757	2,186	249,139	10,476	107,490	519,229
2001	16,062	2,600	251,889	10,863	118,842	521,326
2002	16,803	3,302	261,276	10,684	117,526	552,662
2003	22,506	2,374	276,162	11,872	124,918	584,431
2004	22,440	2,049	275,123	11,784	114,763	582,933
2005	16,166	1,850	257,981	11,784	116,866	552,191
2006	321	0	292,751	13,044	120,821	637,572
2007	105	0	284,431	12,876	116,201	619,739
2008	0	0	230,186	11,183	97,853	555,709
2009	0	0	227,233	10,613	98,550	552,259
2010	0	0	216,352	9,757	90,913	543,883
2011	0	0	212,657	7,602	92,294	580,371
2012	0	0	213,146	6,901	95,420	596,928
2013	0	0	204,817	6,385	92,339	589,498
2014	0	0	205,022	6,382	92,639	601,306
2015	0	0	213,699	6,451	92,053	616,727
2016	0	0	210,595	6,297	83,758	603,498

Table 5. Winter Grade Reformulated Gasoline Sales

Calendar Year	Volume (1000 bbls)					
	MTBE	TAME	Aromatics*	Benzene	Olefins	Saturates
1997	30,738	2,532	65,344	2,180	40,444	206,583
1998	31,763	2,523	68,037	2,309	38,726	207,807
1999	30,587	2,925	68,432	2,347	40,806	211,760
2000	31,180	2,810	69,691	2,469	44,815	224,188
2001	31,190	2,715	69,998	2,414	46,389	219,987
2002	31,344	2,309	73,410	2,504	43,435	233,181
2003	30,815	1,509	74,495	2,541	43,680	237,384
2004	28,805	1,352	75,679	2,581	45,481	244,859
2005	27,401	1,199	77,863	2,728	46,288	245,988
2006	14,366	41	77,998	2,732	44,712	245,336
2007	41	0	75,301	2,639	45,774	248,748
2008	0	0	74,249	2,709	46,002	265,481
2009	0	0	72,692	2,727	44,740	264,818
2010	0	0	71,387	2,638	46,372	263,851
2011	0	0	66,292	2,400	44,691	260,410
2012	0	0	64,164	2,157	41,950	252,779
2013	0	0	62,938	2,033	41,454	253,666
2014	0	0	65,558	2,203	40,740	266,972
2015	0	0	67,810	2,265	40,806	274,958
2016	0	0	69,254	2,223	39,922	282,071

Table 6. Summer Grade Reformulated Gasoline Sales

Calendar Year	Volume (1000 bbls)					
	MTBE	TAME	Aromatics*	Benzene	Olefins	Saturates
1997	26,197	2,349	65,538	1,963	36,575	161,911
1998	26,197	2,349	65,538	1,963	36,575	161,911
1999	27,050	2,398	66,882	2,034	33,395	168,738
2000	26,760	2,676	66,870	2,209	35,473	173,849
2001	28,125	2,956	58,210	1,836	32,979	183,467
2002	28,441	2,838	61,422	1,955	37,207	179,979
2003	29,520	2,507	65,340	1,946	35,622	190,611
2004	28,839	2,686	63,083	1,974	35,603	186,626
2005	25,122	1,422	66,055	1,998	38,597	195,085
2006	22,686	1,487	64,763	2,133	38,457	183,850
2007	508	0	62,000	1,875	34,956	188,224
2008	33	0	61,716	1,858	37,819	193,365
2009	0	0	57,676	1,844	35,259	197,676
2010	0	0	59,516	1,837	37,075	198,202
2011	0	0	59,949	1,892	37,848	205,731
2012	0	0	56,535	1,739	38,634	194,105
2013	0	0	53,322	1,559	37,670	201,013
2014	0	0	51,586	1,531	34,682	194,689
2015	0	0	52,777	1,547	36,545	206,827
2016	0	0	56,599	1,635	37,120	212,468

* Aromatics listed in Tables 3-6 are non-benzene aromatics

Next, the carbon content of each of the various components of summer and winter gasolines is determined based on the API data. Table 7 shows a comparison between the ranges of Aromatics, Olefins and Saturates data in Conventional and Reformulated gasolines from the EPA Trends report and the totals of those components from the API data for the different grades of gasoline. The API data was just used to determine the carbon fraction of winter and summer gasoline components (non-benzene aromatics, olefins and saturates). As can be seen by Table 7, the API data is a reasonable representation of both winter and summer gasolines.

Table 7. Comparison of API data versus EPA Trends data

Component	Winter Grade			Summer Grade		
	Conventional	Reformulated	API	Conventional	Reformulated	API
Aromatics	20.0%-26.2%	18.0%-22.2%	19.1%	23.4%-29.3%	18.2%-25.4%	36.1%
Olefins	9.0%-12.9%	10.1%-13.7%	11.0%	9.3%-13.2%	11.6%-13.8%	10.5%
Saturates	60.9%-70.6%	64.9%-71.7%	69.9%	57.7%-66.7%	60.9%-69.5%	53.4%

Table 8 shows the breakdown of saturated hydrocarbons in summer and winter gasolines and the carbon fraction for each compound based on the API data. Carbon fraction is calculated using a molecular weight of C of 12.0107, molecular weight of H of 1.0079, and molecular weight of O of 15.9994. A similar procedure was done for non-benzene aromatics (Table 9) and olefins (Table 10). Annex 2 describes how the speciated component lists of different grades of gasoline (shown in Tables 8-10) were developed using the API data.

Table 8. Saturated Hydrocarbon Carbon Fraction

Compound	Formula	C	H	Carbon (mass %)	Volume Percent	
					Winter	Summer
n-Butane	C4H10	4	10	82.7%	14.9%	7.1%
n-Pentane	C5H12	5	12	83.2%	7.7%	5.2%
n-Hexane	C6H14	6	14	83.6%	3.1%	3.0%
n-Heptane	C7H16	7	16	83.9%	1.4%	1.3%
n-Octane	C8H18	8	18	84.1%	3.4%	1.7%
n-Nonane	C9H20	9	20	84.3%	3.3%	0.4%
n-Decane	C10H22	10	22	84.4%	2.1%	0.4%
Isobutane	C4H10	4	10	82.7%	0.3%	1.3%
Isopentane	C5H12	5	12	83.2%	13.6%	12.9%
2M-Pentane	C6H14	6	14	83.6%	10.6%	8.4%
3M-Hexane	C7H16	7	16	83.9%	4.9%	5.1%
3M-Heptane	C8H18	8	18	84.1%	4.0%	3.4%
23DM-Butane	C6H14	6	14	83.6%	2.4%	4.3%
24DM-Pentane	C7H16	7	16	83.9%	1.0%	2.4%
23DM-Hexane	C8H18	8	18	84.1%	3.6%	5.8%
224TM-Pentane	C8H18	8	18	84.1%	18.6%	33.0%
225TM-Hexane	C9H20	9	20	84.3%	1.1%	2.4%
3M Octane	C9H20	9	20	84.3%	3.1%	0.7%
226TM Octane	C11H24	11	24	84.5%	0.9%	1.1%
Saturated Hydrocarbon Weighted Carbon Percent					83.6%	83.9%

Table 9. Non-Benzene Aromatics Carbon Fraction

Compound	Formula	C	H	Carbon (mass %)	Volume Percent	
					Winter	Summer
Toluene	C7H8	7	8	91.2%	13.4%	33.5%
Xylene	C8H10	8	10	90.5%	26.2%	17.6%
1,2M, 4E-Benzene	C10H14	10	14	89.5%	7.5%	5.0%
1M3E-Benzene	C9H12	9	12	89.9%	13.4%	14.2%
123TM-Benzene	C9H12	9	12	89.9%	18.2%	22.3%
Cyclopentane	C5H10	5	10	85.6%	2.1%	0.8%
Cyclohexane	C6H12	6	12	85.6%	1.6%	0.6%
M-Cyclopentane	C6H12	6	12	85.6%	9.1%	3.4%
M-Cyclohexane	C7H14	7	14	85.6%	3.2%	0.8%
DM-Cyclopentane	C7H14	7	14	85.6%	5.3%	1.7%
Non-Benzene Aromatics Weighted Carbon Percent					89.3%	90.1%

Table 10. Olefin Carbon Fraction

Compound	Formula	C	H	Carbon (mass %)	Volume Percent	
					Winter	Summer
2M-2-Butene	C5H10	5	10	85.6%	24.5%	22.9%
1-Pentene	C5H10	5	10	85.6%	34.5%	50.5%
1-Hexene	C6H12	6	12	85.6%	40.9%	26.7%
Olefin Weighted Carbon Percent					85.6%	85.6%

Table 11 gives the final carbon fractions for the non-ethanol components of gasoline using the weighted averages from Tables 8 through 10. Carbon fractions for MTBE, TAME, and benzene are calculated based on their chemical formula.

Table 11. Gasoline Component Carbon Fraction

Compound	Carbon (mass %)	
	Winter	Summer
MTBE	68.1%	68.1%
TAME	70.5%	70.5%
Non-Benzene Aromatics	89.3%	90.1%
Benzene	92.3%	92.3%
Olefins	85.6%	85.6%
Saturates	83.6%	83.8%

Using the fuel volume information in Tables 3-6 and carbon fraction information from Table 11, weighted average carbon percent is estimated (Table 12).

Table 12. Weighted Average Non-Ethanol Gasoline Carbon Mass Percent

Calendar Year	Non-Ethanol Gasoline Carbon Mass Percent			
	Conventional		Reformulated	
	Winter	Summer	Winter	Summer
1997	85.2%	85.6%	83.5%	84.0%
1998	85.0%	85.4%	83.5%	83.9%
1999	85.0%	85.5%	83.6%	83.9%
2000	85.1%	85.5%	83.6%	83.7%
2001	85.1%	85.5%	83.6%	83.7%
2002	85.1%	85.5%	83.7%	83.8%
2003	85.1%	85.4%	83.7%	83.8%
2004	85.0%	85.4%	83.8%	84.1%
2005	85.1%	85.5%	83.9%	84.2%
2006	85.3%	85.8%	84.5%	85.4%
2007	85.3%	85.8%	85.1%	85.4%
2008	85.2%	85.7%	85.0%	85.3%
2009	85.2%	85.7%	85.0%	85.3%
2010	85.2%	85.7%	85.0%	85.3%
2011	85.1%	85.5%	84.9%	85.3%
2012	85.1%	85.5%	84.9%	85.2%
2013	85.0%	85.5%	84.9%	85.2%
2014	85.0%	85.4%	84.9%	85.2%
2015	85.0%	85.5%	84.9%	85.2%
2016	85.0%	85.5%	84.9%	85.2%

Next, the densities in Table 2 are combined with the carbon mass weight percent in Table 12 to produce carbon weight per barrel of fuel (Table 13). Note that a barrel of fuel is 42 gallons.

Table 13. Non-Ethanol Gasoline Carbon Fractions (kg/bbl)

Calendar Year	Non-Ethanol Gasoline C Fractions			
	Conventional		Reformulated	
	Winter	Summer	Winter	Summer
1997	99.44	101.48	96.77	99.63
1998	98.98	101.32	97.01	99.63
1999	99.09	101.32	97.07	99.54
2000	99.15	101.67	96.89	98.77
2001	99.48	101.77	97.02	99.09

Calendar Year	Non-Ethanol Gasoline C Fractions			
	Conventional		Reformulated	
	Winter	Summer	Winter	Summer
2002	99.35	101.60	97.06	99.11
2003	99.47	101.74	97.15	99.02
2004	98.78	101.28	97.25	99.50
2005	98.81	101.20	97.40	99.52
2006	99.10	101.75	98.04	100.99
2007	98.95	101.70	98.48	100.63
2008	98.56	100.84	98.06	100.11
2009	98.59	101.01	98.15	100.50
2010	98.42	100.64	98.14	100.34
2011	98.22	100.32	97.68	100.29
2012	97.90	100.08	97.57	99.83
2013	97.72	99.95	97.31	99.71
2014	97.63	99.80	97.13	99.55
2015	97.64	99.82	97.13	99.59
2016	97.66	99.83	97.12	99.59

Next, the higher heating value of non-ethanol gasoline is calculated based upon the energy content of gasoline blendstock and non-ethanol oxygenates per EIA data[5] and the composition of the non-ethanol portion of the gasoline by type, season, and grade. Non-ethanol blendstock higher heating value is 5.253 mmBtu/bbl through 2006 and 5.222 mmBtu/bbl after 2006. The higher heating value of non-ethanol oxygenates is 4.247 mmBtu/bbl. Taking into account the percent of non-ethanol oxygenates in the gasoline and the remaining gasoline blendstock, Table 14 shows the higher heating value for non-ethanol gasoline.

Table 14. Non-Ethanol Gasoline Higher Heating Value (mmBtu/bbl)

Calendar Year	Conventional		Oxygenated		Reformulated	
	Winter	Summer	Winter	Summer	Winter	Summer
1990	5.253	5.253	5.253	5.253	5.253	5.253
1991	5.253	5.253	5.253	5.253	5.253	5.253
1992	5.253	5.253	5.253	5.253	5.253	5.253
1993	5.238	5.229	5.253	5.253	5.253	5.253
1994	5.233	5.227	5.253	5.253	5.253	5.253
1995	5.247	5.245	5.250	5.238	5.158	5.157
1996	5.248	5.244	5.248	5.241	5.171	5.174
1997	5.247	5.243	5.247	5.243	5.171	5.171
1998	5.238	5.239	5.238	5.239	5.188	5.187
1999	5.239	5.238	5.239	5.238	5.183	5.182
2000	5.242	5.240	5.242	5.240	5.188	5.181
2001	5.241	5.240	5.241	5.240	5.192	5.186
2002	5.242	5.239	5.242	5.239	5.194	5.186
2003	5.244	5.241	5.244	5.241	5.211	5.203
2004	5.245	5.244	5.245	5.244	5.225	5.223
2005	5.247	5.247	5.247	5.247	5.228	5.226
2006	5.252	5.253	5.252	5.253	5.237	5.252
2007	5.221	5.222	5.222	5.222	5.222	5.222

[5] EIA, *Monthly Energy Review, Appendix A* at https://www.eia.gov/totalenergy/data/monthly/pdf/sec12_2.pdf

Calendar Year	Conventional		Oxygenated		Reformulated	
	Winter	Summer	Winter	Summer	Winter	Summer
2008	5.222	5.222	5.222	5.222	5.222	5.222
2009	5.222	5.222	5.222	5.222	5.222	5.222
2010	5.221	5.222	5.222	5.222	5.222	5.222
2011	5.221	5.222	5.222	5.222	5.222	5.222
2012	5.221	5.222	5.222	5.222	5.222	5.222
2013	5.221	5.222	5.222	5.222	5.222	5.222
2014	5.221	5.222	5.222	5.222	5.222	5.222
2015	5.221	5.222	5.222	5.222	5.222	5.222
2016	5.221	5.222	5.222	5.222	5.222	5.222
2017	5.222	5.222	5.222	5.222	5.222	5.222
2018	5.222	5.222	5.222	5.222	5.222	5.222

Using the fuel sales in Table 1, the carbon fractions in Table 13, and the higher heating values in Table 14, carbon fractions in terms of million metric tonnes (MMT) per quadrillion Btu (QBtu) are shown in Table 15. These values are compared with the values currently used in the Inventory. Carbon fractions for 1990 through 1996 were assumed to be the same as those for 1997 and carbon fractions for 2017 through 2018 were assumed to be the same as those for 2016. Going forward, data would be updated as new composition data becomes available. As shown in Table 15, the new values are 1.4% to 3.2% lower than the current values.

Table 15. Non-Ethanol Gasoline Carbon Factor (MMT/QBtu)

Calendar Year	New	Current	New vs current
1990	19.11	19.42	-1.6%
1991	19.11	19.44	-1.7%
1992	19.10	19.49	-2.0%
1993	19.11	19.44	-1.7%
1994	19.10	19.36	-1.4%
1995	19.06	19.36	-1.5%
1996	19.05	19.35	-1.6%
1997	19.05	19.36	-1.6%
1998	19.01	19.37	-1.8%
1999	19.03	19.32	-1.5%
2000	19.01	19.33	-1.6%
2001	19.05	19.34	-1.5%
2002	19.03	19.38	-1.8%
2003	19.03	19.36	-1.7%
2004	18.94	19.38	-2.3%
2005	18.94	19.36	-2.2%
2006	19.02	19.45	-2.3%
2007	19.11	19.56	-2.3%
2008	19.00	19.46	-2.3%
2009	19.03	19.46	-2.2%
2010	19.00	19.46	-2.4%
2011	18.94	19.46	-2.6%
2012	18.89	19.46	-2.9%
2013	18.86	19.46	-3.1%
2014	18.83	19.46	-3.2%

Calendar Year	New	Current	New vs current
2015	18.83	19.46	-3.2%
2016	18.84	19.46	-3.2%
2017	18.84	19.46	-3.2%
2018	18.84	19.46	-3.2%

There are a number of elements in the calculations that lead to the differences in the new vs. current factors shown above in Table 15 including:

- Use of the EPA Trends data to represent gasoline MTBE, TAME, Benzene, non-Benzene Aromatics, Olefins and Saturates composition as opposed to the historic NIPER data.
- Basing carbon content of the different gasoline components on the API data as opposed to basing it on assumed representative molecules which resulted in lower assumed carbon fractions. This only impacts non-Benzene Aromatics and Saturates carbon content assumptions[6]. The differences are shown in Table 16.

  Table 16. Comparison of Gasoline Component Carbon Fractions

Compound	Carbon (mass %)		
	Current	API Winter	API Summer
Non-Benzene Aromatics	91.25% (based on toluene)	89.31%	90.14%
Saturates	84.12% (based on octane)	83.64%	83.75%

- Updated heating values. The current approach assumed standard heat contents for motor gasoline of 5.222 mmBtu/bbl for conventional gasoline and 5.150 mmBtu/bbl for reformulated gasoline across the time series. The updated approach, as discussed above, assumes a non-ethanol higher heating value of 5.253 mmBtu/bbl through 2006 and 5.222 mmBtu/bbl after 2006 for both conventional and reformulated gasoline. It also factors in the higher heating value of non-ethanol oxygenates of 4.247 mmBtu/bbl. The update results in increasing the assumed heating value of gasoline by roughly 0.5% across time. An increase in the assumed heating value results in a lower carbon factor per heat content.

Preliminary estimates indicate that incorporating the new carbon factors in the inventory would result in lowering the annual emission estimates by an average of 24.7 MMT CO_2 per year across the time series. This represents an average decrease in petroleum CO_2 emissions across all sectors of 1.1% per year and a decrease in total fossil fuel combustion CO_2 emissions of 0.5% per year. The overall historic and cross-sector contribution trends would not generally be impacted.

[6] The carbon contents of other components are based on molecular formula and did not change. All olefins have the same carbon share because they all have a molecular formula in the form CnH2n so the carbon content is the same in existing vs. updated calculations.

Charge Questions

Gasoline Component Composition:

1. Is the EPA Trends data a good data source for determining gasoline composition? Are there other sources available, including for the full time series 1990-2018 and going forward?
2. Is it reasonable to apply the EPA Trends data across all fuel types (i.e., California fuels not included)?
3. Should the EPA Trends data be used for the full time series or just for years where the NIPER data is not available?
4. If using across the time series, is it reasonable to apply the 1997 results to 1990-1996 and the 2016 results to 2017-2018?

Component Speciation:

1. Is it reasonable to use the API data to speciate gasoline components?
2. Is the approach outlined in Annex 2 of this memo to develop the gasoline speciated components reasonable (see p. 15)?
3. Is the API data representative of different gasoline types? If not, is there a better approach to use?
4. Is the API data representative over time? If not is there a better approach?
5. Are there other gasoline speciation data available?
6. Would it be better to use a representative molecule to represent carbon content of different gasoline components?

Carbon Factor:

1. The carbon factor of each gasoline component is based on a percent by mass and are distributed across the full fuel based on the density of the entire gallon. Should individual densities be used instead? If so is there a good source of data for these densities?
2. The carbon factors are lower than what was found previously; do the updated values seem reasonable?

Heating Value:

1. Is the approach for developing heating values reasonable?
2. Are there other data sources available on heating content?
3. The factor is slightly higher than current factors used; do the update seem reasonable?

Annex 1: EPA Trends Data

Conventional Gasoline:

Year	Volume	Oxygen	API	Ethanol	MTBE	TAME	Aromatics (non-benzene)	Benzene	Olefins	Saturates
	Million Gallons	Wt%	Gravity	Vol%	Vol%	Vol%	Vol%	Vol%	Vol%	Vol%
Winter										
1997	41,270	0.19	61.3	0.03	0.69	0.03	23.85	1.15	12.2	62.05
1998	46,205	0.72	61.5	0.81	1.97	0.23	23.62	1.08	11.2	61.09
1999	47,518	0.74	61.4	0.99	1.78	0.11	23.82	1.08	11.4	60.82
2000	48,297	0.74	61.4	1.19	1.39	0.15	23.72	1.08	12	60.47
2001	49,075	0.77	60.8	1.24	1.54	0.19	24.26	1.14	12.5	59.13
2002	49,720	0.73	61	1.2	1.38	0.27	23.93	1.07	11.8	60.35
2003	47,985	0.83	60.7	1.48	1.5	0.18	23.8	1.1	11.5	60.44
2004	47,701	1.07	61.8	1.94	1.86	0.19	23.52	1.08	11.4	60.01
2005	47,832	1.08	61.9	2.19	1.41	0.18	23.55	1.15	11.6	59.92
2006	47,536	0.21	62	0.48	0.18	0.01	23.53	1.17	11.1	63.53
2007	47,422	0.47	62.2	1.31	0.03	<0.01	23.15	1.15	11.1	63.26
2008	43,231	1.4	62.4	3.94	0.01	<0.01	21.63	1.17	10.4	62.85
2009	43,928	2.27	61.9	6.31	<0.01	<0.01	20.89	1.11	9.79	61.9
2010	44,820	2.95	61.8	8.28	<0.01	<0.01	20.03	0.97	9.44	61.28
2011	49,296	2.97	62	8.41	<0.01	<0.01	19.28	0.72	9.19	62.4
2012	47,268	3.13	62.4	8.82	<0.01	<0.01	18.64	0.66	8.8	63.08
2013	48,568	3.24	62.6	9.06	<0.01	<0.01	18	0.6	8.82	63.52
2014	49,835	3.24	62.7	9.07	<0.01	<0.01	17.61	0.59	8.67	64.06
2015	50,132	3.38	-	9.28	<0.01	<0.01	17.81	0.59	8.31	64.01
2016	49,963	3.41	-	9.5	<0.01	<0.01	18.22	0.58	8.12	63.58
Summer										
1997	38,690	0.27	58.2	0.1	1.08	0.06	26.07	1.13	12.5	59.06
1998	39,072	0.65	58.1	0.59	1.91	0.23	26.26	1.14	11.5	58.37
1999	39,022	0.72	58.2	0.84	1.81	0.13	26.45	1.15	11.8	57.82
2000	38,259	0.66	57.7	0.84	1.62	0.24	27.35	1.15	11.8	57
2001	38,995	0.63	57.5	0.74	1.73	0.28	27.13	1.17	12.8	56.15
2002	40,794	0.71	57.7	0.93	1.73	0.34	26.9	1.1	12.1	56.9
2003	43,360	0.81	57.3	0.98	2.18	0.23	26.75	1.15	12.1	56.61

2004	43,036	0.97	58.1	1.52	2.19	0.2	26.85	1.15	11.2	56.89
2005	40,903	0.95	58.4	1.75	1.66	0.19	26.49	1.21	12	56.7
2006	44,907	0.16	58.2	0.44	0.03	<0.01	27.38	1.22	11.3	59.63
2007	43,968	0.46	58.2	1.29	0.01	<0.01	27.17	1.23	11.1	59.2
2008	39,141	1.41	59.2	3.97	<0.01	<0.01	24.7	1.2	10.5	59.63
2009	39,799	2.23	58.6	6.22	<0.01	<0.01	23.98	1.12	10.4	58.28
2010	39,405	2.93	58.9	8.24	<0.01	<0.01	23.06	1.04	9.69	57.97
2011	40,933	2.95	59.2	8.38	<0.01	<0.01	21.82	0.78	9.47	59.55
2012	42,009	3.1	59.5	8.78	<0.01	<0.01	21.31	0.69	9.54	59.68
2013	41,258	3.23	59.6	9.09	<0.01	<0.01	20.85	0.65	9.4	60.01
2014	41,882	3.25	59.8	9.21	<0.01	<0.01	20.56	0.64	9.29	60.3
2015	43,006	3.34	-	9.28	<0.01	<0.01	20.87	0.63	8.99	60.23
2016	41,979	3.41	-	9.54	<0.01	<0.01	21.07	0.63	8.38	60.38

Reformulated Gasoline:

Year	Volume	Oxygen	API	Ethanol	MTBE	TAME	Aromatics (non-benzene)	Benzene	Olefins	Saturates
	Million Gallons	Wt%	Gravity	Vol%	Vol%	Vol%	Vol%	Vol%	Vol%	Vol%
Winter										
1997	14,771	2.2	62.5	1.1	8.74	0.72	18.58	0.62	11.5	58.74
1998	14,922	2.22	62	1.16	8.94	0.71	19.15	0.65	10.9	58.49
1999	15,167	2.16	62	1.18	8.47	0.81	18.95	0.65	11.3	58.64
2000	15,951	2.12	62.4	1.22	8.21	0.74	18.35	0.65	11.8	59.03
2001	15,840	2.11	62.2	1.18	8.27	0.72	18.56	0.64	12.3	58.33
2002	16,435	2.09	62.2	1.31	8.01	0.59	18.76	0.64	11.1	59.59
2003	16,678	2.14	62.1	1.68	7.76	0.38	18.76	0.64	11	59.78
2004	17,209	2.38	62	2.68	7.03	0.33	18.47	0.63	11.1	59.76
2005	17,358	2.37	61.9	2.86	6.63	0.29	18.84	0.66	11.2	59.52
2006	17,388	3.11	61.3	6.96	3.47	0.01	18.84	0.66	10.8	59.26
2007	17,320	3.63	61.3	9.67	0.01	<0.01	18.26	0.64	11.1	60.32
2008	18,057	3.63	61.9	9.65	<0.01	<0.01	17.27	0.63	10.7	61.75
2009	17,896	3.63	61.7	9.65	<0.01	<0.01	17.06	0.64	10.5	62.15
2010	17,868	3.65	61.7	9.68	<0.01	<0.01	16.78	0.62	10.9	62.02
2011	17,380	3.66	62.4	9.67	<0.01	<0.01	16.02	0.58	10.8	62.93

2012	16,780	3.64	62.6	9.63	<0.01	<0.01	16.06	0.54	10.5	63.27
2013	16,741	3.67	63	9.66	<0.01	<0.01	15.79	0.51	10.4	63.64
2014	17,460	3.67	63.3	9.68	<0.01	<0.01	15.77	0.53	9.8	64.22
2015	17,946	3.68	-	9.7	<0.01	<0.01	15.87	0.53	9.55	64.35
2016	18,305	3.68	-	9.72	<0.01	<0.01	15.89	0.51	9.16	64.72
Summer										
1997	12,489	2.15	58	0.95	8.81	0.79	22.04	0.66	12.3	54.45
1998	12,751	2.13	57.9	1.02	8.91	0.79	22.03	0.67	11	55.58
1999	13,069	2.11	58.1	1.07	8.6	0.86	21.49	0.71	11.4	55.87
2000	13,067	2.24	58.9	1.14	9.04	0.95	18.71	0.59	10.6	58.97
2001	13,243	2.21	58.5	1.1	9.02	0.9	19.48	0.62	11.8	57.08
2002	13,853	2.25	58.5	1.3	8.95	0.76	19.81	0.59	10.8	57.79
2003	13,594	2.3	58.6	1.5	8.91	0.83	19.49	0.61	11	57.66
2004	14,220	2.55	58.2	3.04	7.42	0.42	19.51	0.59	11.4	57.62
2005	13,573	2.49	58.4	3.03	7.02	0.46	20.04	0.66	11.9	56.89
2006	13,347	3.52	57.6	9.5	0.16	0.01	19.51	0.59	11	59.23
2007	13,693	3.54	58.2	9.58	0.01	<0.01	18.93	0.57	11.6	59.31
2008	13,586	3.57	58.9	9.59	<0.01	<0.01	17.83	0.57	10.9	61.11
2009	13,780	3.55	58.3	9.59	<0.01	<0.01	18.14	0.56	11.3	60.41
2010	14,193	3.56	58.5	9.62	<0.01	<0.01	17.74	0.56	11.2	60.88
2011	13,522	3.56	58.6	9.61	<0.01	<0.01	17.56	0.54	12	60.29
2012	13,639	3.57	59.2	9.6	<0.01	<0.01	16.42	0.48	11.6	61.9
2013	13,123	3.57	59.4	9.59	<0.01	<0.01	16.51	0.49	11.1	62.31
2014	13,828	3.57	59.6	9.58	<0.01	<0.01	16.03	0.47	11.1	62.82
2015	14,303	3.57	-	9.61	<0.01	<0.01	16.62	0.48	10.9	62.39
2016	15,056	3.58	-	9.63	<0.01	<0.01	16.59	0.51	10.5	62.77

Notes on tables: These do not include California gasolines. Aromatics (non-benzene) calculated by removing benzene % from total aromatics.

Annex 2: API Gasoline Speciation Data Calculations

We used gasoline speciation data from the API ethanol blending study[7]. Of the total of 27 summer gasolines and 10 summertime blendstock for oxygenate blending (BOBs) which were collected and speciated for the analysis by API, we chose a low-RVP summer gasoline and we also picked a winter gasoline which contained an amount of aromatics which is typical of today's winter gasoline (today's gasoline contains about 20 volume percent aromatics). The list of gasoline constituents was sorted and the 33[8] most prevalent constituents were identified (two other constituents are reserved for ethanol and water). Since similar constituents were grouped together, a total of about 60 speciated hydrocarbons were represented by the list of 33 most prevalent constituents, representing a little more than 80 weight percent of the total volume of the speciated sample. To avoid the effects of volatility on the assessment of the effect of different gasoline constituents and water levels on RVP when ethanol is blended into gasoline, we adjusted the butane levels to closely match the RVPs of the several summertime gasolines that we evaluated. To avoid over-representing the very volatile constituents and overestimating the RVP of the speciated, representative gasoline, only the C8 and heavier hydrocarbons were increased to represent the approximately 20 weight percent of the unaccounted for gasoline blend (This is also reasonable because most of the gasoline hydrocarbons unaccounted for by the 35 substances modeled in the activity coefficient model are C8 and heavier).

[7] Ethanol Blending Study and Spreadsheet provided by David Lax, American Petroleum Institute.

[8] 32 components are shown in Tables 8-10 since benzene is listed separately.