ANNEX 7 Uncertainty

The annual U.S. *Inventory* presents the best effort to produce emission estimates for greenhouse gas source and sink categories in the United States. These estimates were generated according to the UNFCCC reporting guidelines, following the recommendations set forth in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006) and *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2019). This Annex provides an overview of the overall uncertainty analysis conducted to support the U.S. *Inventory*, including the sources of uncertainty characterized throughout the *Inventory* associated with various source categories (including emissions and sinks), and the methods used to collect, quantify, and present this uncertainty information. An Addendum to Annex 7 is also prepared separately and includes additional information related to the uncertainty characteristics of input variables used in the development of the overall uncertainty estimates reported in Section 1.7 of the *Inventory* report.

7.1. Overview

The uncertainty analysis conducted in support of the *Inventory* (1) evaluates the relative contribution of the input parameters to the uncertainty associated with each source or sink category estimate, (2) determines the quantitative uncertainty associated with the emission source and sink estimates presented in the main body of this report and (3) estimates the uncertainty in the overall emissions and removals for the latest year, the base year and in the emissions trend. Note, overall uncertainty estimates in the *Inventory* capture quantifiable uncertainties in the input activity and emission factors data, but do not account for the potential of additional sources of uncertainty such as modeling uncertainties, measurement errors, and misreporting or misclassification. Thus, the U.S. *Inventory* uncertainty analysis helps inform and prioritize improvements for source and sink categories estimation process which are discussed in the "Planned Improvements" sections of each source or sink category's discussion within the main body of the report. For each source or sink category, the uncertainty analysis highlights opportunities for changes to data measurement, data collection, and calculation methodologies to reduce uncertainties.

For some category estimates, the uncertainty ranges or bounds are smaller, such as CO_2 emissions from energy-related combustion activities. This is primarily because the methodologies and data utilized for these estimates have remained stable over time, which tends to minimize fluctuations in uncertainty bounds. However, it is important to note that this does not necessarily imply smaller absolute uncertainties, but rather a smaller relative variation in uncertainty over time. Importantly, if a large source were updated for the base year of 1990 with higher uncertainty bounds, it may contribute to an increase in the uncertainty of the overall emission estimates for the base year. For some other limited categories of emissions, uncertainties could have a larger impact on the uncertainties of estimates presented (i.e., storage factors of non-energy uses of fossil fuels). In all source and sink category chapters, the inventory emission (or removal) estimates include "Uncertainty" sections that consider both quantitative and qualitative assessments of uncertainty, considering factors consistent with good practices noted in Volume 1, Chapter 3 of the *2006 IPCC Guidelines* (e.g., completeness of data, representativeness of data and models, sampling errors, measurement errors). The two major types of uncertainty associated with these emission estimates are (1) model uncertainty, which arises when the emission and/or removal estimation models used in developing the *Inventory* estimates do not fully and accurately characterize the respective emission and/or removal processes (due to a lack of technical details or other resources), and (2) parameter uncertainty, which arises due to potential bias or a lack of accurate, complete, representative, or precise input data such as emission factors and activity data and inherent variability.

The uncertainty associated with emission (or removal) estimation models can be partially analyzed by comparing the model emission (or removal) results with those of other models developed to characterize the same emission (or removal) process, after taking into account differences in their conceptual framework, capabilities, data, and underlying assumptions. However, in many cases it would be very difficult—if not impossible—to use this approach to quantify the model uncertainty associated with the emission estimates in this report, primarily because most categories only have a single model that has been developed to estimate emissions. Therefore, model uncertainty was not quantified in this report. Nonetheless, it has been discussed qualitatively, where appropriate, along with the individual source or sink category description and inventory estimation methodology.

Parameter uncertainty encompasses several causes such as lack of completeness, lack of data or representative data, sampling error, random or systematic measurement error, or misreporting or misclassification. Uncertainties associated

with input emission parameters have been quantified for all of the emission sources and sinks included in the U.S. *Inventory* totals.

7.2. Methodology and Results

The United States has developed both a quality assurance and quality control (QA/QC) and uncertainty management plan (EPA 2018). Like the QA/QC plan, the uncertainty management plan is part of a continually evolving process. The uncertainty management plan provides for a quantitative assessment of the *Inventory* analysis itself, thereby contributing to continuing efforts to understand both what causes uncertainty and how to improve *Inventory* and accuracy. Although the plan provides both general and specific guidelines for implementing a quantitative uncertainty analysis, its components are intended to evolve over time, consistent with the inventory estimation process. The U.S. plan includes procedures and guidelines, and forms and templates, for developing quantitative assessments of uncertainty in the national Inventory estimates (EPA 2018). For the 1990 through 2022 *Inventory,* EPA has used the uncertainty management plan as well as the methodology presented in the *2006 IPCC Guidelines* and *2019 Refinement.*

The *2006 IPCC Guidelines* and *2019 Refinement* recommend two methods—Approach 1 and Approach 2—for developing quantitative estimates of uncertainty associated with individual categories and the overall *Inventory* estimates. The United States is continuing efforts to develop quantitative estimates of uncertainty for all source categories using Approach 2. In following the UNFCCC requirement under Article 4.1 and the Paris Agreement, emissions from International Bunker Fuels, Wood Biomass and Biofuel Consumption, and Indirect Greenhouse Gas Emissions are not included in the total emissions estimated for the U.S. *Inventory*; therefore, no quantitative uncertainty estimates have been developed for these categories.[145] CO_2 Emissions from Biomass and Biofuel Consumption are accounted for implicitly in the Land Use, Land-Use Change and Forestry (LULUCF) chapter through the calculation of changes in carbon stocks. The Energy sector provides an estimate of CO_2 emissions from Biomass and Biofuel Consumption as a memo item for informational purposes, consistent with the UNFCCC and Paris Agreement reporting requirements.

Approach 1 and Approach 2 Methods

The Approach 1 method for estimating uncertainty is based on the propagation of errors, as shown in Eq. 3.1 and Eq. 3.2 of the *2006 IPCC Guidelines* and *2019 Refinement*. These equations combine the random component of uncertainty associated with the activity data and the emission (or the other) factors. Inherent in employing the Approach 1 method are the assumptions that, for each source and sink category, (i) both the uncertainties in the activity data and the emission factor values are approximately normally distributed, (ii) the coefficient of variation (i.e., the ratio of the standard deviation to the mean) associated with each input variable is less than 30 percent, and (iii) the input variables within and across sub- source categories are not correlated (i.e., value of each variable is independent of the values of other variables).

The Approach 2 method is preferred if (i) the uncertainty associated with the input variables is large (i.e., >30 percent), (ii) the distributions of uncertainties in the underlying the input variables are not normal (e.g., triangular or uniformly distributed), (iii) the estimates of uncertainty associated with the input variables are correlated, and/or if (iv) a complex estimation methodology and/or several input variables are used to characterize the emission (or removal) process. Due to the input parameters and estimation methodologies used in the *Inventory*, the uncertainties are assessed using the Approach 2 method for all categories where sufficient and reliable data are available to characterize the uncertainty of the input variables.

The Approach 2 method employs the Monte Carlo Stochastic Simulation technique (also referred to as the Monte Carlo method). Under this method, emission (or removal) estimates for a particular source (or sink) category are estimated by randomly selecting values of emission factors, activity data, and other estimation parameters according to their individual Probability Density Functions (PDFs). This process is repeated many times using computer software, in order to build up the probability density function, which is then used to estimate the final uncertainty values of the overall emission (or removal) estimates for that source (or sink). For most categories, the Monte Carlo approach is implemented using commercially available simulation software such as Palisade's @RISK Microsoft Excel add-in.

[145] However, because the input variables that determine the emissions from the Fossil Fuel Combustion and the International Bunker Fuels source categories are correlated, uncertainty associated with the activity variables in the International Bunker Fuels was taken into account in estimating the uncertainty associated with the Fossil Fuel Combustion.

Characterization of Uncertainty in Input Variables

Both Approach 1 and Approach 2 uncertainty analyses require that all the input variables have defined PDFs. In the absence of sufficient data measurements, data samples, or expert judgments that determined otherwise, the PDFs incorporated in the current source or sink category uncertainty analyses were limited to normal, lognormal, uniform, triangular, pert, and beta distributions. The choice among these six PDFs depended largely on the observed or measured data and expert judgment. If no additional uncertainty information is available then the previous year's *Inventory* uncertainty data is used. Input variables with asymmetrical PDFs shift the overall output which can lead to asymmetrical bounds for a source (or sink) category and in turn, for the overall *Inventory* uncertainty analysis.

Individual Source and Sink Category Inventory Uncertainty Estimates

The main report provides an overview of the input parameters and sources of uncertainty for each source and sink category within the Uncertainty section of each category. Table A-246 summarizes results based on assessments of source and sink category-level uncertainty, as presented in the main chapter text. The table presents base year (1990) and current year (2022) emissions for each source and sink category. The combined uncertainty (at the 95 percent confidence interval) for each source and category is expressed as the percentage above and below the total 2022 emissions estimated for each source and sink category. Uncertainty in the trend of each source and sink category is described subsequently in this Appendix.

Table A-246: Summary Results of Source and Sink Category Uncertainty Analyses

Source or Sink Category	Base Year Emissions[a]	2022 Emissions[b]	2022 Uncertainty[b]	
	($MMT CO_2$ Eq.)	($MMT CO_2$ Eq.)	Lower Bound	Upper Bound
CO_2	**5,131.7**	**5,053.0**	**-2%**	**4%**
Fossil Fuel Combustion	4,752.2	4,699.4	-2%	4%
Non-Energy Use of Fuels	99.1	102.8	-31%	62%
Cement Production	33.5	41.9	-4%	5%
Iron and Steel Production & Metallurgical Coke Production	104.7	40.7	-16%	15%
Natural Gas Systems	32.4	36.5	-12%	15%
Petrochemical Production	20.1	28.8	-4%	4%
Petroleum Systems	9.6	22.0	-19%	25%
Ammonia Production	14.4	12.6	-4%	4%
Incineration of Waste	12.9	12.4	-16%	16%
Lime Production	11.7	12.2	-1%	1%
Other Process Uses of Carbonates	7.1	10.4	-12%	15%
Urea Consumption for Non-Agricultural Purposes	3.8	7.1	-4%	4%
Urea Fertilization	2.4	5.3	-43%	3%
Carbon Dioxide Consumption	1.5	5.0	-5%	5%
Liming	4.7	3.3	-124%	126%
Coal Mining	4.6	2.5	-69%	75%
Glass Production	2.3	2.0	-3%	2%
Soda Ash Production	1.4	1.7	-14%	3%
Titanium Dioxide Production	1.2	1.5	-13%	13%
Aluminum Production	6.8	1.4	-3%	3%
Ferroalloy Production	2.2	1.3	-13%	13%
Zinc Production	0.6	0.9	-19%	20%
Phosphoric Acid Production	1.5	0.8	-15%	25%
Lead Production	0.5	0.4	-15%	15%
Carbide Production and Consumption	0.2	0.2	-10%	10%
Magnesium Production and Processing	0.1	+	-6%	7%
Abandoned Oil and Gas Wells	+	+	-83%	235%
Substitution of Ozone Depleting Substances	+	+	-4%	15%
Ceramics Production	+	+	NE	NE
Wood Biomass, Ethanol, and Biodiesel	*237.9*	*305.4*	*NE*	*NE*

Consumption[c]				
International Bunker Fuels[d]	*103.6*	*98.2*	*NE*	*NE*
CH_4	**871.7**	**702.4**	**-14%**	**14%**
Enteric Fermentation	183.1	192.6	-31%	31%
Natural Gas Systems	218.8	173.1	-18%	17%
Landfills	197.8	119.8	-8%	15%
Manure Management	39.1	64.7	-22%	22%
Coal Mining	108.1	43.6	-20%	9%
Petroleum Systems	49.4	39.6	-18%	23%
Wastewater Treatment	22.7	20.8	-29%	33%
Rice Cultivation	18.9	18.9	-73%	73%
Stationary Combustion	9.7	8.6	-31%	122%
Abandoned Oil and Gas Wells	7.8	8.5	-83%	230%
Abandoned Underground Coal Mines	8.1	6.3	-22%	20%
Mobile Combustion	7.2	2.6	12%	12%
Composting	0.4	2.6	-58%	58%
Field Burning of Agricultural Residues	0.5	0.6	-11%	11%
Carbide Production and Consumption	+	+	-10%	11%
Iron and Steel Production & Metallurgical Coke Production	+	+	-7%	7%
Ferroalloy Production	+	+	-12%	13%
Petrochemical Production	+	+	-14%	14%
Anaerobic Digestion at Biogas Facilities	+	+	-54%	54%
Incineration of Waste	+	+	NE	NE
International Bunker Fuels[d]	*0.2*	*0.1*	*NE*	*NE*
N_2O	**408.2**	**389.7**	**-17%**	**26%**
Agricultural Soil Management	288.8	290.8	-30%	37%
Stationary Combustion	22.3	24.7	-33%	35%
Wastewater Treatment	14.8	21.9	-37%	196%
Manure Management	13.4	16.9	-31%	31%
Mobile Combustion	38.4	16.7	-5%	5%
Nitric Acid Production	10.8	8.6	-5%	5%
N_2O from Product Uses	3.8	3.8	-24%	24%
Adipic Acid Production	13.5	2.1	-4%	4%
Composting	0.3	1.8	-58%	58%
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.5	1.3	-31%	31%
Incineration of Waste	0.4	0.3	-52%	163%
Electronics Industry	+	0.3	-11%	11%
Field Burning of Agricultural Residues	0.2	0.2	-13%	13%
Natural Gas Systems	+	0.2	-12%	15%
Petroleum Systems	+	+	-19%	25%
International Bunker Fuels[d]	*0.8*	*0.8*	*NE*	*NE*
HFCs, PFCs, SF_6 and NF_3	**125.5**	**198.1**	**-8%**	**10%**
Substitution of Ozone Depleting Substances	0.3	178.1	-4%	15%
Fluorochemical Production	70.9	7.8	-19%	19%
Electrical Equipment	24.7	5.1	-25%	25%
Electronics Industry	3.3	4.4	-6%	6%
Magnesium Production and Processing	5.6	1.1	-8%	8%
Aluminum Production	19.3	0.8	-7%	8%
SF_6 and PFCs from Other Product Use	1.4	0.8	-36%	38%
Total Gross Emissions[e]	**6,536.9**	**6,343.2**	**-2%**	**4%**
LULUCF Emissions[f]	57.9	67.5	-5%	8%
LULUCF Carbon Stock Change Flux[g]	(1,034.7)	(921.8)	26%	-19%
LULUCF Sector Net Total[h]	**(976.7)**	**(854.2)**	**28%**	**20%**
Net Emissions (Sources and Sinks)[e]	**5,560.2**	**5,489.0**	**-5%**	**6%**

Notes: Totals may not sum due to independent rounding. Parentheses indicate net sequestration. Total emissions (excluding emissions for which uncertainty was not quantified) are presented without LULUCF. Net emissions are presented with LULUCF. Uncertainty for the base year is available upon request.

+ Does not exceed 0.05 MMT CO_2 Eq. or 0.5 percent.

NE (Not Estimated)

[a] Base Year is 1990 for all sources.

[b] The uncertainty estimates correspond to a 95 percent confidence interval, with the lower bound corresponding to 2.5th percentile and the upper bound corresponding to 97.5th percentile.

[c] Emissions from Wood Biomass and Biofuel Consumption are not included in the energy sector totals.

[d] Emissions from International Bunker Fuels are not included in the totals.

[e] Totals exclude emissions for which uncertainty was not quantified.

[f] LULUCF emissions include the CH_4 and N_2O emissions reported for peatlands remaining peatlands, forest fires, drained organic soils, grassland fires, and coastal wetlands remaining coastal wetlands; CH_4 emissions from land converted to coastal wetlands, land converted to flooded land, and flooded land remaining flooded land; and N_2O emissions from forest soils and settlement soils.

[g] LULUCF carbon stock change is the net C stock change from the following categories: forest land remaining forest land, land converted to forest land, cropland remaining cropland, land converted to cropland, grassland remaining grassland, land converted to grassland, wetlands remaining wetlands, land converted to wetlands, settlements remaining settlements, and land converted to settlements. Since the resulting flux is negative the signs of the resulting lower and upper bounds are reversed.

[h] The LULUCF sector net total is the net sum of all CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

Overall (Aggregate) *Inventory* Level Uncertainty Estimates

The overall level uncertainty estimate for the U.S. *Inventory* was developed using the IPCC Approach 2 uncertainty estimation methodology for 1990 and 2022. The overall *Inventory* uncertainty estimates were estimated by combining the Monte Carlo simulation output data for each emission source or sink category (as described above) into a comprehensive overall uncertainty model. This overall uncertainty model combines uncertainties and produces uncertainty results at the gas level. If such detailed output data were not available for a particular source or sink category, individual PDFs were assigned based on the most detailed data available from the category-specific quantitative uncertainty analysis. The overall *Inventory* uncertainty was then derived through the resulting PDF of the combined emissions data.

For select categories such as composting, several LULUCF source categories, and parts of Agricultural Soil Management source categories, Approach 1 uncertainty results were used in the overall uncertainty analysis. However, for all other emission sources, Approach 2 uncertainty results were used in the overall uncertainty estimation.

The overall uncertainty model results indicate that the 1990 U.S. greenhouse gas emissions are estimated to be within the range of approximately 6,354.3 to 6,792.8 MMT CO_2 Eq., reflecting a relative 95 percent confidence interval uncertainty range of -3 percent to 4 percent with respect to the total U.S. greenhouse gas emission estimate of approximately 6,536.9 MMT CO_2 Eq. The uncertainty interval associated with total CO_2 emissions, ranges from -2 percent to 4 percent of total CO_2 emissions estimated. The results indicate that the uncertainty associated with the inventory estimate of the total CH_4 emissions ranges from -16 percent to 9 percent, uncertainty associated with the total inventory N_2O emission estimate ranges from -14 percent to 26 percent, and uncertainty associated with fluorinated greenhouse gas (F-GHG) emissions ranges from -13 percent to 22 percent. When the LULUCF sector is included in the analysis, the uncertainty is estimated to be -6 to 6 percent of Net Emissions (sources and sinks) in 1990. The uncertainties presented are quantifiable uncertainties in the input activity and emission factors data, not uncertainties in the models, data representativeness, measurement errors, or misreporting or misclassification of data.

Table A-247: Quantitative Uncertainty Assessment of Overall National Inventory Emissions for 1990 (MMT CO_2 Eq. and Percent)

Gas	1990 Emission Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Greenhouse Gas Estimate[a] (MMT CO_2 Eq.)		(%)		Mean[b] (MMT CO_2 Eq.)	Standard Deviation[b] (MMT CO_2 Eq.)
		Lower Bound[c]	Upper Bound[c]	Lower Bound	Upper Bound		
CO_2	5,131.6	5,008.2	5,348.2	-2%	4%	5,098.2	88.0
CH_4[d]	871.7	731.3	948.4	-16%	9%	701.5	56.3
N_2O[d]	408.2	349.7	513.0	-14%	26%	434.8	41.6
PFCs, HFCs, SF_6, and NF_3[d]	125.5	108.6	152.9	-13%	22%	207.3	11.6
Total Gross Emissions	**6,536.9**	**6,354.3**	**6,792.8**	**-3%**	**4%**	**6,441.8**	**113.3**
LULUCF Emissions[e]	57.9	55.2	61.9	-5%	7%	68.7	1.7
LULUCF Carbon Stock Change Flux[f]	(1,034.7)	(1,296.1)	(845.3)	25%	-18%	(957.3)	116.7
LULUCF Sector Net Total[g]	**(976.7)**	**(1,237.7)**	**(787.8)**	**27%**	**-19%**	**(888.6)**	**116.7**
Net Emissions (Sources and Sinks)	**5,560.2**	**5,247.0**	**5,882.2**	**-6%**	**6%**	**5,553.3**	**161.4**

[a] The lower and upper bounds for emission estimates correspond to a 95 percent confidence interval, with the lower bound corresponding to 2.5th percentile and the upper bound corresponding to 97.5th percentile.

[b] Mean value indicates the arithmetic average of the simulated emission estimates; standard deviation indicates the extent of deviation of the simulated values from the mean.

[c] The lower and upper bound emission estimates for the sub-source categories do not sum to total emissions because the low and high estimates for total emissions were calculated separately through simulations.

[d] The overall uncertainty estimates did not take into account the uncertainty in the GWP values for CH_4, N_2O, and high GWP gases used in the inventory emission calculations for 1990.

[e] LULUCF emissions include the CH_4 and N_2O emissions reported for peatlands remaining peatlands, forest fires, drained organic soils, grassland fires, and coastal wetlands remaining coastal wetlands; CH_4 emissions from land converted to coastal wetlands, land converted to flooded land, and flooded land remaining flooded land; and N_2O emissions from forest soils and settlement soils.

[f] LULUCF carbon stock change is the net C stock change from the following categories: forest land remaining forest land, land converted to forest land, cropland remaining cropland, land converted to cropland, grassland remaining grassland, land converted to grassland, wetlands remaining wetlands, land converted to wetlands, settlements remaining settlements, and land converted to settlements. Since the resulting flux is negative the signs of the resulting lower and upper bounds are reversed.

[g] The LULUCF sector net total is the net sum of all CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

Notes: Totals may not sum due to independent rounding. Parentheses indicate net sequestration. Total emissions (excluding emissions for which uncertainty was not quantified) are presented without LULUCF. Net emissions are presented with LULUCF.

The overall uncertainty model results indicate that the 2022 U.S. greenhouse gas emissions are estimated to be within the range of approximately 6,190.3 to 6,604.8 MMT CO_2 Eq., reflecting a relative 95 percent confidence interval uncertainty range of -2 percent to 4 percent with respect to the total gross U.S. greenhouse gas emission estimate of approximately 6,343.2 MMT CO_2 Eq. The uncertainty interval associated with total CO_2 emissions, which constitute about 79.7 percent of the total U.S. greenhouse gas emissions in 2022, ranges from -2 percent to 4 percent of total CO_2 emissions estimated. The results indicate that the uncertainty associated with the inventory estimate of the total CH_4 emissions ranges from -14 percent to 14 percent, uncertainty associated with the total inventory N_2O emission estimate ranges from -17 percent to 26 percent, and uncertainty associated with fluorinated greenhouse gas (F-GHG) emissions ranges from -8 percent to 10 percent. When the LULUCF sector is included in the analysis, the uncertainty is estimated to be -5 to 6 percent of Net Emissions (sources and sinks) in 2022.

The uncertainty of total gross and net emissions was reduced this year due to improvements in methods and data compared to the previous *Inventory*; the 95 percent uncertainty bounds for total gross emissions are -2 percent to 4 percent for the current (1990 through 2022) *Inventory* compared to -2 percent to 6 percent for the previous (1990 through 2021) *Inventory* and the bounds for net emissions are -5 percent to 6 percent for the current (1990 through 2022) *Inventory* compared to -4 percent to 6 percent for the previous (1990 through 2021) *Inventory*. This reflects improvements made to different categories. For example, the 95 percent uncertainty bounds for carbon dioxide emissions from Petrochemical Production were reduced from -5 percent to 6 percent in the previous (1990 through

2021) *Inventory* to -4 percent to 4 percent in the current (1990 through 2022) *Inventory*. The 95 percent uncertainty bounds for nitrous oxide emissions from manure management were reduced from -34 percent to 193 percent in the previous (1990 through 2021) *Inventory* to -32 percent to 32 percent in the current (1990 through 2022) *Inventory*. Furthermore, SF_6 and PFCs from Other Product Use and Fluorochemical Production were added to F-GHG emissions and Electronics Industry was broken out by gas this *Inventory*, improving the emissions estimates and the corresponding uncertainty bounds.

Compared to 1990, the uncertainty of total gross and net emissions did not change significantly this year; the 95 percent uncertainty bounds for total gross emissions are -2 percent to 4 percent for the current (1990 through 2022) *Inventory* compared to -3 percent to 4 percent for 1990 and the bounds for net emissions are -5 percent to 6 percent for the current (1990 through 2022) *Inventory* compared to -6 to 6 percent for 1990. However, this does not mean that the methodology and data quality was not improved for *Inventory* emissions estimates, rather it reflects offsetting impacts from improvements where uncertainty both decreased and increased (i.e., the latter represents situations where a more realistic acknowledgement of the limitations of emissions estimates is reflected in the input data), as noted in the 2006 IPCC Guidelines. More detail on changes in uncertainty can be found under "Recent and Ongoing Improvements."

A summary of the overall quantitative uncertainty estimates is shown below.

Table A-248: Quantitative Uncertainty Assessment of Overall National Inventory Emissions for 2022 (MMT CO_2 Eq. and Percent)

Gas	2022 Emission Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Greenhouse Gas Estimate[a] (MMT CO_2 Eq.)		Uncertainty Range Relative to Greenhouse Gas Estimate[a] (%)		Mean[b] (MMT CO_2 Eq.)	Standard Deviation[b] (MMT CO_2 Eq.)
		Lower Bound[c]	Upper Bound[c]	Lower Bound	Upper Bound		
CO_2	5,053.0	4,937.3	5,257.7	-2%	4%	5,095.2	81.9
CH_4[d]	702.4	604.3	803.1	-14%	14%	703.8	52.0
N_2O[d]	389.7	324.6	490.2	-17%	26%	399.5	42.3
PFC, HFC, SF_6, and NF_3[d]	198.1	182.8	217.5	-8%	10%	199.5	9.0
Total Gross Emissions	**6,343.2**	**6,190.3**	**6,604.8**	**-2%**	**4%**	**6,397.9**	**106.3**
LULUCF Emissions[e]	67.5	64.3	73.2	-5%	8%	68.6	2.3
LULUCF Carbon Stock Change Flux[f]	(921.8)	(1,158.6)	(748.7)	26%	-19%	(957.5)	105.3
LULUCF Sector Net Total[g]	**(854.2)**	**(1,090.3)**	**(680.5)**	**28%**	**-20%**	**(888.8)**	**105.3**
Net Emissions (Sources and Sinks)	**5,489.0**	**5,216.2**	**5,801.9**	**-5%**	**6%**	**5,509.0**	**150.6**

[a] The lower and upper bounds for emission estimates correspond to a 95 percent confidence interval, with the lower bound corresponding to 2.5th percentile and the upper bound corresponding to 97.5th percentile.

[b] Mean value indicates the arithmetic average of the simulated emission estimates; standard deviation indicates the extent of deviation of the simulated values from the mean.

[c] The lower and upper bound emission estimates for the sub-source categories do not sum to total emissions because the low and high estimates for total emissions were calculated separately through simulations.

[d] The overall uncertainty estimates did not take into account the uncertainty in the GWP values for CH_4, N_2O, and high GWP gases used in the inventory emission calculations for 2022.

[e] LULUCF emissions include the CH_4 and N_2O emissions reported for peatlands remaining peatlands, forest fires, drained organic soils, grassland fires, and coastal wetlands remaining coastal wetlands; CH_4 emissions from land converted to coastal wetlands, land converted to flooded land, and flooded land remaining flooded land; and N_2O emissions from forest soils and settlement soils.

[f] LULUCF carbon stock change is the net C stock change from the following categories: forest land remaining forest land, land converted to forest land, cropland remaining cropland, land converted to cropland, grassland remaining grassland, land converted to grassland, wetlands remaining wetlands, land converted to wetlands, settlements remaining settlements, and land converted to settlements. Since the resulting flux is negative the signs of the resulting lower and upper bounds are reversed.

[g] The LULUCF sector net total is the net sum of all CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

Notes: Totals may not sum due to independent rounding. Parentheses indicate net sequestration. Total emissions (excluding emissions for which uncertainty was not quantified) are presented without LULUCF. Net emissions are presented with LULUCF.

As summarized, uncertainty in 2022 is similar to overall uncertainty in 1990, and this is due to offsetting impacts from changes in uncertainty from methodological improvements over the time series. As indicated in section 3.1.7 (Implications of Methodological Choice) in Volume 3, *2006 IPCC Guidelines*, while in some cases methodological refinements have reduced uncertainty (as noted below), in some cases, in particular for key categories, they can also increase uncertainty with improved representation of the "complexity of the system" (IPCC 2006). For example, this is true of uncertainty associated with inputs to estimating N_2O emissions from Agricultural Soil Management.

Trend Uncertainty

In addition to the estimates of uncertainty associated with the current and base year emission estimates, this Annex also presents the estimates of trend uncertainty. The *2006 IPCC Guidelines* define trend as the difference in emissions between the base year (i.e., 1990) and the current year (i.e., 2022) *Inventory* estimates. However, for purposes of understanding the concept of trend uncertainty, the emission trend is defined in this *Inventory* as the percentage change in the emissions (or removal) estimated for the current year, relative to the emission (or removal) estimated for the base year. The uncertainty of the trend is "a function of the uncertainties of the activity data and the emission factors at both these points in time", as defined in the *2019 IPCC Refinement*. The uncertainty associated with this emission trend is referred to as trend uncertainty.

Under the Approach 1 method, there are two types of uncertainty to consider when estimating the trend uncertainty in an individual source or sink category. As described in the *2006 IPCC Guidelines*, correlated (Type A) uncertainties are estimated by comparing the change in emissions trend given a 1 percent change in both base (i.e., 1990) and current emissions (i.e., 2022), while uncorrelated or random errors in the emissions trend (Type B) are estimated by comparing the change in emissions trend given a 1 percent change in only the current year emissions. When combined, both types of uncertainty capture the sensitivity in trend emission estimates to sources of uncertainty that are correlated between the base and current year (Type A), as well as the random component of uncertainty in the emission estimates (Type B).

Under the Approach 2 method, the trend uncertainty is estimated using the Monte Carlo Stochastic Simulation technique. As described in the *2006 IPCC Guidelines*, this Approach follows four steps. First, the PDFs for emission factors, activity data, and other input estimation parameters are determined for both the current and base year. For purposes of this *Inventory*, due to data limitations, for some categories where uncertainty assessments for 1990 are undergoing updates for future reports but were not ready to incorporate for this submission, a simple approach has been adopted, under which the base year source or sink category emissions are assumed to exhibit the same uncertainty characteristics as the current year emissions (or removals). Source and sink category-specific PDFs for base year estimates were developed using current year (i.e., 2022) uncertainty output data. These were adjusted to account for differences in magnitude between the two years' inventory estimates. The second and third steps follow the Monte Carlo approach described previously to calculate repeated emission estimates for each source and sink category in the base and current years according to the input data PDFs. The overall *Inventory* trend uncertainty estimate was developed by combining all source and sink category-specific trend uncertainty estimates. These trend uncertainty estimates represent the 95 percent confidence interval of the estimated percent change in emissions between 1990 and 2022 and are shown in Table A-249.

Table A-249: Quantitative Assessment of Trend Uncertainty (MMT CO_2 Eq. and Percent)

Gas/Source	Base Year Emissions[a]	2022 Emissions	Emissions Trend	Trend Range[b]	
	(MMT CO_2 Eq.)		(%)	(%)	
				Lower Bound	Upper Bound
CO_2	**5,131.6**	**5,053.0**	**-2%**	**-6%**	**3%**
Fossil Fuel Combustion	4,752.2	4,699.4	-1%	-6%	4%
Non-Energy Use of Fuels	99.10	102.8	4%	-36%	82%
Cement Production	33.5	41.9	25%	11%	42%
Iron and Steel Production & Metallurgical Coke Production	104.7	40.7	-61%	-69%	-51%
Natural Gas Systems	32.4	36.5	12%	-16%	31%
Petrochemical Production	20.1	28.8	43%	24%	44%
Petroleum Systems	9.6	22.0	129%	60%	228%
Ammonia Production	14.4	12.6	-12%	-16%	13%

Incineration of Waste	12.9	12.4	-4%	-24%	21%
Lime Production	11.7	12.2	4%	2%	7%
Other Process Uses of Carbonates	7.1	10.4	46%	39%	103%
Urea Consumption for Non-Agricultural Purposes	3.8	7.1	86%	60%	123%
Urea Fertilization	2.4	5.3	120%	26%	290%
Carbon Dioxide Consumption	1.5	5.0	240%	197%	289%
Liming	4.7	3.3	-30%	-716%	658%
Coal Mining	4.6	2.5	-46%	-86%	92%
Glass Production	2.3	2.0	-14%	-18%	-11%
Soda Ash Production	1.4	1.7	19%	5%	35%
Titanium Dioxide Production	1.2	1.5	23%	3%	48%
Aluminum Production	6.8	1.4	-79%	-80%	-78%
Ferroalloy Production	2.2	1.3	-38%	-48%	-27%
Zinc Production	0.6	0.9	50%	14%	96%
Phosphoric Acid Production	1.5	0.8	-45%	-59%	-25%
Lead Production	0.5	0.4	-17%	-33%	2%
Carbide Production and Consumption	0.2	0.2	-14%	-29%	7%
Abandoned Oil and Gas Wells	+	+	13%	-1479%	1536%
Magnesium Production and Processing	0.1	+	-98%	-98%	-98%
Ceramics Production	+	+	NA	NE	NE
Substitution of Ozone Depleting Substances	+	+	NA	NE	NE
Wood Biomass and Biofuel Consumption[c]	237.9	305.4	28%	*NE*	*NE*
International Bunker Fuels[d]	*103.6*	*98.2*	*-5%*	*NE*	*NE*
CH_4	**871.7**	**702.4**	**-19%**	**-32%**	**-2%**
Enteric Fermentation	183.1	192.6	5%	-49%	119%
Natural Gas Systems	218.8	173.1	-21%	-38%	2%
Landfills	197.8	119.8	-39%	-46%	-3%
Manure Management	39.1	64.7	65%	-2%	183%
Coal Mining	108.1	43.6	-60%	-68%	-50%
Petroleum Systems	49.4	39.6	-20%	-41%	5%
Wastewater Treatment	22.7	20.8	-8%	-41%	41%
Rice Cultivation	18.9	18.9	0%	-584%	836%
Stationary Combustion	9.7	8.6	-11%	-63%	174%
Abandoned Oil and Gas Wells	7.8	8.5	9%	-87%	808%
Abandoned Underground Coal Mines	8.1	6.3	-22%	-45%	9%
Mobile Combustion	7.2	2.6	-64%	-66%	-54%
Composting	0.4	2.6	505%	162%	1311%
Field Burning of Agricultural Residues	0.5	0.6	14%	-10%	46%
Carbide Production and Consumption	+	+	-38%	-45%	-9%
Iron and Steel Production & Metallurgical Coke Production	+	+	-68%	-70%	-55%
Ferroalloy Production	+	+	-45%	-48%	-27%
Petrochemical Production	+	+	-22%	-98%	-94%
Anaerobic Digestion at Biogas Facilities	+	+	1109%	400%	2822%
Incineration of Waste	+	+	-18%	NE	NE
International Bunker Fuels[d]	*0.2*	*0.1*	*-52%*	*NE*	*NE*
N_2O	**408.2**	**389.7**	**-5%**	**-30%**	**51%**
Agricultural Soil Management	288.8	290.8	1%	-34%	89%
Stationary Combustion	22.3	24.7	11%	-47%	69%
Wastewater Treatment	14.8	21.9	48%	-54%	296%
Manure Management	13.4	17.0	27%	-21%	106%
Mobile Combustion	38.4	16.7	-57%	-66%	-35%
Nitric Acid Production	10.8	8.6	-20%	-34%	-24%
N_2O from Product Uses	3.8	3.8	0%	-34%	13%
Adipic Acid Production	13.5	2.1	-85%	-87%	-85%
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.5	1.3	-11%	-50%	28%

Incineration of Waste	0.4	0.3	-18%	-77%	180%
Electronics Industry	+	0.3	720%	444%	950%
Natural Gas Systems	0.0	0.2	3205%	2346%	4338%
Field Burning of Agricultural Residues	0.2	0.2	15%	-10%	47%
Petroleum Systems	+	+	282%	142%	512%
International Bunker Fuels[d]	*0.8*	*0.8*	*1%*	*NE*	*NE*
HFCs, PFCs, SF_6, and NF_3	**125.5**	**198.1**	**58%**	**32%**	**95%**
Substitution of Ozone Depleting Substances	0.3	178.1	70367%	61763%	80308%
Electrical Equipment	24.7	5.1	-79%	-89%	-74%
Electronics Industry	3.3	4.4	35%	20%	54%
Aluminum Production	19.3	0.8	-96%	-96%	-96%
SF_6 and PFCs from Other Product Use	1.4	0.8	-45%	-70%	27%
HCFC-22 Production	+	+	NA	NE	NE
Total Gross Emissions[e]	**6,536.9**	**6,343.2**	**-3%**	**-7%**	**3%**
LULUCF Emissions[f]	57.9	67.5	17%	6%	30%
LULUCF Carbon Stock Change Flux[g]	(1,034.7)	(921.8)	-11%	-35%	21%
LULUCF Sector Net Total[h]	**(976.7)**	**(854.2)**	**-13%**	**-37%**	**21%**
Net Emissions (Sources and Sinks)[e]	**5,560.2**	**5,489.0**	**-1%**	**-8%**	**8%**

+ Does not exceed 0.05 MMT CO_2 Eq. or 0.5 percent.

NE (Not Estimated)

[a] Base Year is 1990 for all sources.

[b] The trend range represents a 95 percent confidence interval for the emission trend, with the lower bound corresponding to 2.5th percentile value and the upper bound corresponding to 97.5th percentile value.

[c] Emissions from Wood Biomass and Biofuel Consumption are not included specifically in the energy sector totals.

[d] Emissions from International Bunker Fuels are not included in the totals.

[e] Totals exclude emissions for which uncertainty was not quantified.

[f] LULUCF emissions include the CH_4 and N_2O emissions reported for peatlands remaining peatlands, forest fires, drained organic soils, grassland fires, and coastal wetlands remaining coastal wetlands; CH_4 emissions from land converted to coastal wetlands, land converted to flooded land, and flooded land remaining flooded land; and N_2O emissions from forest soils and settlement soils.

[g] LULUCF carbon stock change is the net C stock change from the following categories: forest land remaining forest land, land converted to forest land, cropland remaining cropland, land converted to cropland, grassland remaining grassland, land converted to grassland, wetlands remaining wetlands, land converted to wetlands, settlements remaining settlements, and land converted to settlements.

[i] The LULUCF sector net total is the net sum of all CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

Notes: Totals may not sum due to independent rounding. Parentheses indicate net sequestration. Total emissions (excluding emissions for which uncertainty was not quantified) are presented without LULUCF. Net emissions are presented with LULUCF.

7.3. Information on Uncertainty Analyses by Source and Sink Category

The quantitative uncertainty estimates associated with each emission and removal category are reported within sectoral chapters of this *Inventory* following the discussions of inventory estimates and their estimation methodology. To better understand the uncertainty analysis details, refer to the respective chapters and Uncertainty sections in the body of this report. EPA provides additional documentation on uncertainty information consistent with the guidance presented in Table 3.3 in Vol. 1, Chapter 3 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006) in an Uncertainty Addendum. Due to the number of detailed tables, it is not published with the *Inventory* but is available upon request. EPA plans to publish this in a more easily accessible format with future reports (e.g., the 2025 *Inventory* report). All uncertainty estimates are reported relative to the current *Inventory* estimates for the 95 percent confidence interval, unless otherwise specified.

7.4. Reducing Uncertainty and Planned Improvements

The United States has implemented many improvements over the last several years that have reduced uncertainties across the source and sink categories. These improvements largely result from new data sources that provide more accurate data and/or increased data coverage, as well as other methodological and completeness improvements, as described below.

Box A-1: Reducing Uncertainty

The *2006 IPCC Guidelines* provides the following guidance for ways to reduce *Inventory* uncertainty and improve the quality of an *Inventory* and its uncertainty estimates.

- *Improving conceptualization*. Improving the inclusiveness of the structural assumptions chosen can reduce uncertainties. An example is better treatment of seasonality effects that leads to more accurate annual estimates of emissions or removals for the Agriculture, Land Use, Land Use Change and Forestry sector.
- *Improving models.* Improving the model structure and parameterization can lead to better understanding and characterization of the systematic and random errors, as well as reductions in these causes of uncertainty.
- *Improving representativeness.* This may involve stratification or other sampling strategies. For example, continuous emissions monitoring systems (CEMS) can be used to reduce uncertainty for some sources and gases as long as the representativeness is guaranteed. CEMS produces representative data at the facilities where it is used, but in order to be representative of an entire source category, CEMS data must be available for a random sample or an entire set of individual facilities that comprise the category. When using CEMS both concentration and flow will vary, requiring simultaneous sampling of both attributes.
- *Incorporating excluded emission sources.* Quantitative estimates for some of the sources and sinks of greenhouse gas emissions, such as from some land-use activities, industrial processes, and parts of mobile sources, could not be developed at this time either because data are incomplete or because methodologies do not exist for estimating emissions from these source categories. See Annex 5 of this report for a discussion of the sources of greenhouse gas emissions and sinks excluded from this report. Consistent with IPCC good practice principles, EPA continues efforts to estimate emissions and sinks from excluded emission and removal sources occurring in U.S. and developing uncertainty estimates for all source and sink categories for which emissions and removals are estimated.
- *Collecting more measured data.* Uncertainty associated with bias and random sampling error can be reduced by increasing the sample size and filling in data gaps. This applies to both measurements and surveys.
- *Using more precise measurement methods.* Measurement error can be reduced by using more precise measurement methods, avoiding simplifying assumption, and ensuring that measurement technologies are appropriately used and calibrated.
- *Eliminating known risk of bias.* This is achieved by ensuring instrumentation is properly positioned and calibrated, models or other estimation procedures are appropriate and representative, and by applying expert judgements in a systematic way.
- *Improving state of knowledge.* Improve the understanding of categories and processes leading to emissions and removals, which can help to discover and correct for problems in incompleteness. It is *Good Practice* to continuously improve emissions and removal estimates based on new knowledge.

The following sections describe the ongoing and planned *Inventory* and uncertainty analysis improvements in the context of these specific areas.

Recent and Ongoing Improvements

To *collect more measured data*, *improve representativeness,* and *use more precise measurement methods,* several source categories in the *Inventory* now use the U.S. EPA's Greenhouse Gas Reporting Program (GHGRP) data, which improves *Inventory* emission (or sink) estimation methods by allowing the incorporation of country-specific data rather than using default IPCC estimates. EPA's GHGRP relies on facility-level data reported from large facilities emitting over 25,000 metric tons of CO_2 equivalent each year. See Annex 9 for more information on use of GHGRP data in the *Inventory*.

In addition to improving *Inventory* input data and methodologies, the use of EPA's GHGRP data can also reduce uncertainty in select *Inventory* emission categories. For example, replacing highly uncertain emission factor estimates

with GHGRP data for the coal mining category reduced the 95 percent uncertainty bounds for methane emissions from this category from -15 percent to 18 percent in the 1990 to 2011 inventory down to -20 percent to 9 percent in the current (1990 through 2022) *Inventory*. Petroleum systems included updates to basin-specific activity factors, leading to increased modeling granularity and a decrease in uncertainty bounds for CH_4 ranging from -18 percent to 25 percent. This represents an improvement from the previous *Inventory*, in which uncertainty bounds ranged from -28 percent to 32 percent. Methane emission estimates from MSW landfills were also revised with GHGRP data, which resulted in methodological and data quality improvements that also reduced the 95 percent uncertainty bounds for this category compared to the prior use of default emission factors with larger assumed uncertainties. The 95 percent uncertainty bounds for this category were reduced from -19 percent to 26 percent in the previous (1990 through 2021) *Inventory* down to -8 percent to 14 percent in the current (1990 through 2022) *Inventory*. Of note, some of the improvements with GHGRP data have been for less significant categories, such as within the IPPU sector, and have not had a significant impact on overall trends within the uncertainty assessment.

Methodological and data quality improvements were also made for HFCs, PFCs, SF_6 and NF_3, including breaking out electrical equipment, by gas and adding Fluorochemical Production as a category, which includes HFC-22 production. However, some improvements to significant *Inventory* emission categories do not necessarily reduce uncertainties as improvements, including improving completeness and moving to higher tiers may still reflect increased knowledge or better representation of the activity and emissions. For example, the 95 percent uncertainty bounds for HFCs, PFCs, SF_6 and NF_3 were -3 percent to 13 percent in the 1990 through 2021 *Inventory*, and they are -4 percent to 14 percent in this current (1990 through 2022) Inventory. Other improvements to significant categories or shifts to higher tier methods over time, such as for agricultural soil management, may also increase uncertainties each year. The 95 percent uncertainty bounds for nitrous oxide emissions from agricultural soil management were increased from -25 percent to 29 percent in 1990 to -30 percent to 72 percent in 2022. These changes account for underestimating uncertainties with lower-tier methods and "reveal a more realistic acknowledgment of the limitations of existing knowledge," as acknowledged by the *2006 IPCC Guidelines*, Volume 1, Chapter 3.1.7. Furthermore, some methods and data for emission categories have not changed significantly over time, such as for sources of CO_2 from fossil fuel combustion, and therefore uncertainties have not changed significantly either.

Additional ongoing improvements to the U.S. *Inventory* uncertainty analyses for select categories will help to *eliminate or reduce known risk of bias, improve models,* and advance *the state of knowledge,* which may lead to further *Inventory* and uncertainty analysis improvements in other areas including *improved conceptualization* and *data representativeness*. Finally, ongoing improvements include review of documentation of source-specific input data and references, PDF distributions, and Monte Carlo analysis results through the implementation of standardized source-specific uncertainty reporting and documentation templates. Ongoing improvements to the overall *Inventory* Uncertainty Analysis documentation will additionally ensure consistency with IPCC *Good Practice* and increase the transparency of the overall analysis.

Planned Improvements

EPA continuously seeks new knowledge to improve the *Inventory* emissions and removal estimates. With available resources, planned future improvements to the *Inventory* and Uncertainty Analysis are prioritized by focusing improvements on categories identified in the Key Category Analysis (Chapter 1.5), or by quantitatively comparing the relative contributions of uncertainties from various input parameters (e.g., activity data and emission factors) to the total uncertainty levels within a source or sink category. Quantifying the sensitivity of the overall *Inventory* uncertainty bounds to the uncertainty within each source or sink category can also prioritize future *Inventory* updates.

As described in Chapter 1.5, Key Categories in the current (1990 to 2022) *Inventory* include (but are not limited to) categories that fall under fossil fuel combustion (Chapter 3.1), petroleum and natural gas systems (Chapter 3.6 and 3.7), Industrial Processes and Product Use (Chapter 3), and Agriculture (Chapter 4). Planned improvements for these key categories largely include the incorporation of more accurate and/or representative input parameters and making corresponding updates to the uncertainty assessments. For example, as described in Chapter 3.1, planned inventory improvements for emissions from fossil fuel combustion categories include efforts to assess the incorporation of more measured input activity data (e.g., GHGRP data, domestic marine activity) and other input parameters (e.g., updated carbon factors for petroleum fuels, emission factors for non-road equipment, etc.). Similarly, Chapters 3.6 and 3.7 discuss plans to continue stakeholder engagement to assess the potential for incorporating new input data (e.g., from peer-reviewed publications, industry studies, etc.), updating methods for select sources (e.g., Offshore Production, unassigned high-emitters), or including new sources (e.g., anomalous leak events) within the petroleum and natural gas

system categories. Categories within the IPPU sector (Chapter 4) also discuss plans to assess the future incorporation of additional facility-level GHGRP data, improve emission models (e.g., for ozone depleting substance substitutes) and the methodological descriptions in the *Inventory* report. Similar to other categories, planned improvements to Agricultural emissions from manure management and enteric fermentation include the incorporation of new, more accurate and representative data, updates to emission models and conceptualization (including moving to Tier 2 methods for all sources), as well as revised uncertainty estimates to the account for recent updates. Details describing the planned improvements for these and nearly all other individual source and sink categories are included in the category-specific chapters of this report.

Implementation of these planned improvements will occur on an ongoing basis as new information becomes available. Improvements are prioritized to make best use of available resources, including efforts to improve the accuracy of emission factors, collect more detailed and representative activity data, as well as provide better estimates of input parameter uncertainty. For example, further research is needed in some cases to improve the accuracy of emission factors, including those currently applied to CH_4 and N_2O emissions from manure management. Lastly, for many individual source categories, further research is also needed to characterize the PDFs of their input parameters more accurately (e.g., emission factors and activity data). This might involve using measured or published statistics or implementing a rigorous protocol to elicit expert judgment, if published or measured data are not available. Continued efforts in these areas will reduce *Inventory* uncertainty and increase the completeness, accuracy, and transparency of the category-specific and overall *Inventory* estimates.

Additional planned improvements for the overall *Inventory* uncertainty analysis include improving the presentation of uncertainties in a format consistent with suggested tables in Volume 1, Chapter 3 of the *2006 IPCC Guidelines*. As resources permit, in particular for key categories, improvements include reviewing and updating the existing uncertainty models for the base year. This process would improve the base year and trend uncertainty analyses but may not eliminate every simplifying assumption described above due to limited data availability in the base year.

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