9. Recalculations and Improvements

Each year, many emission and sink estimates in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* are recalculated and revised, as efforts are made to improve the estimates through the use of better methods and/or data with the goal of improving inventory quality and reducing uncertainties, including the transparency, completeness, consistency, and overall usefulness of the report. In this effort, the United States follows the *2006 IPCC Guidelines* (IPCC 2006), which state, "Both methodological changes and refinements over time are an essential part of improving inventory quality. It is *good practice* to change or refine methods when available data have changed; the previously used method is not consistent with the IPCC guidelines for that category; a category has become key; the previously used method is insufficient to reflect mitigation activities in a transparent manner; the capacity for inventory preparation has increased; improved inventory methods become available; and/or for correction of errors."

When methodological changes have been implemented, the previous Inventory's time series (i.e., 1990 to 2020) is assessed and potentially recalculated to reflect the change, per guidance in IPCC (2006). Changes in historical data are often the result of changes in statistical data supplied by other agencies, and these changes do not necessarily impact the entire time series. In addition, the current Inventory updates GWPs for calculating CO_2-equivalent emission estimates of non-CO_2 gases (CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3) to reflect updated science. This inventory has been revised to use the 100-year GWPs provided in the IPCC *Fifth Assessment Report* (AR5) (IPCC 2013). AR5 GWP values differ from those presented in the IPCC *Fourth Assessment Report* and used in the previous Inventories as required by earlier UNFCCC reporting guidelines. Recent decisions under the UNFCCC[1] require Parties to use 100-year GWP values from the IPCC *Fifth Assessment Report* (AR5) for calculating CO_2-equivalence in their national reporting (IPCC 2013) by the end of 2024. In preparation for upcoming UNFCCC requirements[2], this report reflects CO_2-equivalent greenhouse gas totals using 100-year AR5 GWP values. Note, all estimates provided in sectoral chapters of this report are presented in both CO_2 equivalents and unweighted units.

The results of all methodological changes and historical data updates made in the current Inventory are presented in Figure 9-1, Table 9-3, and Table 9-4. Figure 9-1 presents the impact of recalculations by sector and on net total emissions across the timeseries. Table 9-1 and Table 9-2 include the quantitative effects of methodological changes as well as the impacts of updating GWPs from AR4 to AR5 in calculating CO_2-equivalent U.S. greenhouse gas emissions by gas across the Energy, Industrial Processes and Product Use (IPPU), Agriculture, Land Use, Land Use Change and Forestry, and Waste sectors. Table 9-3 summarizes the quantitative effect of all methodology and data changes on U.S. greenhouse gas emissions by gas across the Energy, Industrial Processes and Product Use (IPPU), Agriculture, and Waste sectors. Finally, Table 9-4 similarly summarizes the quantitative effect of methodology and data changes on annual net fluxes from Land Use, Land-Use Change, and Forestry (LULUCF). The

[1] See paragraphs 1 and 2 of the decision on common metrics adopted at the 27th UNFCCC Conference of Parties (COP27) available online here: https://unfccc.int/sites/default/files/resource/sbsta2022_L25a01E.pdf. The UNFCCC reporting guidelines require use of the 100-year GWPs listed in table 8.A.1 in Annex 8.A of Chapter 8 of the *Fifth Assessment Report* of the Intergovernmental Panel on Climate Change, excluding the value for fossil methane.

[2] See Annex to decision 18/CMA.1 available online at https://unfccc.int/sites/default/files/resource/CMA2018_03a02E.pdf.

tables below present results relative to the previously published Inventory (i.e., the 1990 to 2020 report) in units of million metric tons of carbon dioxide equivalent (MMT CO_2 Eq.). To understand the details of any specific recalculation or methodological improvement, see the Recalculations within each source/sink categories' section found in Chapters 3 through 7 of this report. A discussion of Inventory improvements in response to review processes is described in Annex 8.

The use of AR5 GWP values in this Inventory results in time-series recalculations for most inventory sources. In Table 9-1 below, recalculations are presented including both the quantitative effect of the data and methodological changes as well as the quantitative effect of the change in using the AR5 GWP.

The Inventory includes new categories not included in the previous Inventory that improve completeness of the national estimates. Specifically, the current report includes CO_2 emissions from substitution of ozone depleting substances, and the reporting of CO_2 from the biogenic components of municipal solid waste as a memo item.

The following source and sink categories underwent the most significant methodological and historical data changes. A brief summary of the recalculations and/or improvements undertaken are provided for these categories.

- *Forest Land Remaining Forest Land: Changes in Forest Carbon Stocks (CO_2).* The methods used in the current Inventory to compile estimates for forest ecosystem carbon stocks and stock changes and harvested wood products (HWPs) from 1990 through 2021 are consistent with those used in the previous (1990 through 2020) Inventory. Population estimates of carbon stocks and stock changes were compiled using NFI data from each U.S. state and national estimates were compiled by summing over all states. New NFI data in most states were incorporated in the latest Inventory which contributed to lower forest land area estimates and carbon stocks, particularly in Alaska with new data from 2018 to 2021. Fire data sources were also updated for Alaska through 2021 and this, combined with the new NFI data for the years 2018 through 2021, resulted in substantial changes in carbon stocks. These changes can be attributed to obtaining plot-level soil orders using the more refined gridded National Soil Survey Geographic Database (gNATSGO) dataset (Soil Survey Staff 2020a, 2020b), rather than the Digital General Soil Map of the United States (STATSGO2) dataset which had been used in previous Inventories. This resulted in a structural change in the soil carbon estimates for mineral and organic soils across the entire time series, particularly in Alaska where new data on forest area was included for the years 2018 through 2021. Finally, recent land-use change in Alaska (since 2015) also contributed to variability in soil carbon stocks and stock changes in recent years in the time series. New data included in the HWP time-series result in a minor decrease (<1 percent) in carbon stocks in the HWP pools but a substantial increase (60 percent) in the carbon stock change estimates for Products in Use and to a lesser extent (2 percent) in SWDS between the previous Inventory and the current Inventory. With the easing of the global pandemic and the return of consumers to the marketplace, there was a rebound in the purchase and accumulation of both paper and solid wood products. These changes resulted in an average annual increase in C stock change losses of 31.9 MMT CO_2 Eq. (4.4 percent), across the 1990 through 2020 time series, relative to the previous Inventory. See Chapter 6, Section 6.2 for more information on recalculations.
- *Wetlands Remaining Wetlands: Emissions from Flooded Land Remaining Flooded Land (CH_4).* The 1990 through 2021 Inventory uses the National Wetlands Inventory (NWI) as the primary data source for flooded land surface area, whereas the 1990 through 2020 Inventory report used the National Hydrography Data (NHD) as the primary geospatial data source. The NWI is far more detailed than the NHD, resulting in increased emission estimates across the time series. The NWI also includes Alaska, Hawaii, and Puerto Rico, which were not included in the 1990 through 2020 Inventory. Emissions from reservoirs in Flooded Land Remaining Flooded Land were further increased by correcting the creation date of several large reservoirs in South Dakota, North Dakota, Alabama, Arkansas, Georgia, and South Carolina. These reservoirs were incorrectly classified as Land Converted to Flooded Land for a portion of the 1990 through 2020 time series but are classified as Flooded Land Remaining Flooded Land throughout the 1990 through 2021 Inventory time series. The 1990 through 2020 Inventory distinguished between reservoirs and inundation areas. Inundation areas were defined as periodically flooded lands that

bordered a permanently flooded reservoir. The NWI includes both permanently and periodically flooded lands, but does not consistently discriminate between them, therefore inundation areas and reservoirs are consolidated into reservoirs for the 1990 through 2021 Inventory. The net effect of these recalculations was an average annual increase in CH_4 emission estimates from reservoirs of 23.4 MMT CO_2 Eq. (107.1 percent) over the time series.

- *Biomass and Biofuel Consumption (CO_2).* The CO_2 emissions associated with the biogenic components of MSW combustion were added to this year's report as a memo item. The emissions were calculated based on the same approach used to develop fossil CO_2 emissions from the fossil components of MSW as described in Section 3.3. The result of these changes was an increase in biogenic CO_2 emissions reported as a memo item relative to the previous Inventory. See Chapter 3, Section 3.10 for more information on recalculations.

- *Petroleum Systems (CH_4).* In this Inventory, an update that incorporates additional basin-level data from GHGRP Subpart W was implemented for several emission sources in the onshore production segment, including for pneumatic controllers, equipment leaks, chemical injection pumps, and storage tanks. For each of these emission sources, EPA modified the calculation methodology to use GHGRP data to develop basin-specific activity factors and/or emission factors. The combined impact of revisions to 2020 petroleum systems CH_4 emission estimates on a CO_2-equivalent basis, compared to the previous Inventory, is an increase from 45.0 to 54.5 MMT CO_2 Eq. (9.4 MMT CO_2 Eq., or 20.9 percent). The recalculations resulted in higher CH_4 emission estimates on average across the 1990 through 2020 time series, compared to the previous Inventory, by 5.7 MMT CO_2 Eq., or 12.0 percent. See Chapter 3, Section 3.6 for more information on recalculations.

- *Land Converted to Grassland: Changes in all Ecosystem Carbon Stocks (CO_2).* Recalculations are associated with new FIA data from 1990 to 2021 on biomass, dead wood and litter C stocks associated with conversions from Cropland Converted to Grassland (woodlands), Other Land Converted to Grassland, and Settlements Converted to Grassland; updated FIA data from 1990 to 2021 on biomass, dead wood and litter C stocks from Forest Land Converted to Grassland; and updated estimates for mineral soils from 2016 to 2021 using the linear extrapolation method. As a result, Land Converted to Grassland has an estimated increase in C stock changes of 2.9 MMT CO_2 Eq. (23.2 percent) on average over the time series.

- *Land Converted to Cropland: Changes in all Ecosystem Carbon Stocks (CO_2).* Recalculations are associated with new FIA data from 1990 to 2021 on biomass, dead wood and litter C stocks in Grassland Converted to Cropland (i.e., woodland conversion to cropland), updated FIA data from 1990 to 2021 on biomass, dead wood and litter C stocks in Forest Land Converted to Cropland, and updated estimates for mineral soils from 2016 to 2021 using the linear extrapolation method. As a result, Land Converted to Cropland has an estimated larger C loss of 2.6 MMT CO_2 Eq. (4.9 percent) on average over the time series. See Chapter 6, Section 6.5 for more information on recalculations.

- *Natural Gas Systems (CH_4).* In this Inventory, an update that incorporates additional basin-level data from GHGRP Subpart W was implemented for several emission sources in the onshore production segment, including for pneumatic controllers, equipment leaks, chemical injection pumps, storage tanks, and liquids unloading. For each of these emission sources, EPA modified the calculation methodology to use GHGRP data to develop basin-specific activity factors and/or emission factors. The combined impact of revisions to 2020 natural gas systems CH_4 emissions, compared to the previous Inventory, is an increase from 184.7to 185.4 MMT CO_2 Eq. (0.7 MMT CO_2 Eq., or 0.4 percent). The recalculations resulted in an average increase in the annual CH_4 emission estimates across the 1990 through 2020 time series, compared to the previous Inventory, of 2.6 MMT CO_2 Eq., or 1.4 percent. See Chapter 3, Section 3.7 for more information on recalculations.

- *Fossil Fuel Combustion (CO_2).* Several updates to activity data and emission factors led to recalculations of previous year results. The major updates include updated data from EIA sources (2022a) for energy consumption statistics, industrial energy sector activity data, natural gas consumption, and petroleum

statistics across the time series relative to the previous Inventory. The carbon content for propylene was updated from 65.95 kg CO_2/MMBtu to 67.77 kg CO_2/MMBtu to reflect values used in the EPA Greenhouse Gas Emission Factors Hub. Fuel consumption for the U.S. Territories provided by EIA's International Energy Statistics (EIA 2022b) was updated across the time series. Updates were also made to the values of natural gas used for ammonia production which led to changes in energy sector adjustments. Overall, these revisions impacted estimates from the combustion of fossil fuels in a number of ways including decreased petroleum emissions from the residential sector, decreased petroleum emissions from U.S. Territories, increased natural gas emissions across all economic sectors, and decreased coal emissions from U.S. Territories. These changes resulted in an average annual increase of 2.5 MMT CO_2 Eq. (12 percent) in CO_2 emissions from fossil fuel combustion relative to the previous Inventory. See Chapter 3, Section 3.1 for more information on recalculations.

- *Land Converted to Settlements: Changes in all Ecosystem Carbon Stocks (CO_2).* Recalculations are associated with new FIA data from 1990 to 2021 on biomass, dead wood and litter C stocks in Forest Land Converted to Settlements and woodland conversion associated with Grassland Converted to Settlements, and updated estimates for mineral and organic soils from 2016 to 2021 using the linear extrapolation method. As a result, Land Converted to Settlements has an estimated larger C loss of 2.3 MMT CO_2 Eq. on average over the time series. This represents a 2.9 percent increase in C stock changes for Land Converted to Settlements compared to the previous Inventory. See Chapter 6, Section 6.11 for more information on recalculations.

- *Forest Land Remaining Forest Land: Non-CO_2 Emissions from Forest Fires (CH_4 and N_2O).* The methods used in the current (1990 through 2021) Inventory to compile estimates of non-CO_2 emissions from forest fires represent a slight change relative to the previous (1990 through 2020) Inventory. The basic components of calculating forest fire emissions (IPCC 2006) remain unchanged, but the WFEIS-based estimates now include estimates of area burned from both MTBS and MODIS as well as two alternate fuel models to improve consistency across the time series and accuracy with use of updated data. An additional source of change leading to recalculations are recent and ongoing updates to the MTBS fire records (i.e., including both most-recent as well as possible updates to past years' fires). The net result of implementing the improvements listed above was an average annual increase of 2.2 MMT CO_2 Eq., or 44.7 percent, in total non-CO_2 emissions from forest fires across the entire time series. See Chapter 6, Section 6.2 for more information on recalculations.

Figure 9-1: Impacts from Recalculations to U.S. Greenhouse Gas Emissions by Sector, Including Quantitative Change Related to the Use of AR5 GWP Values

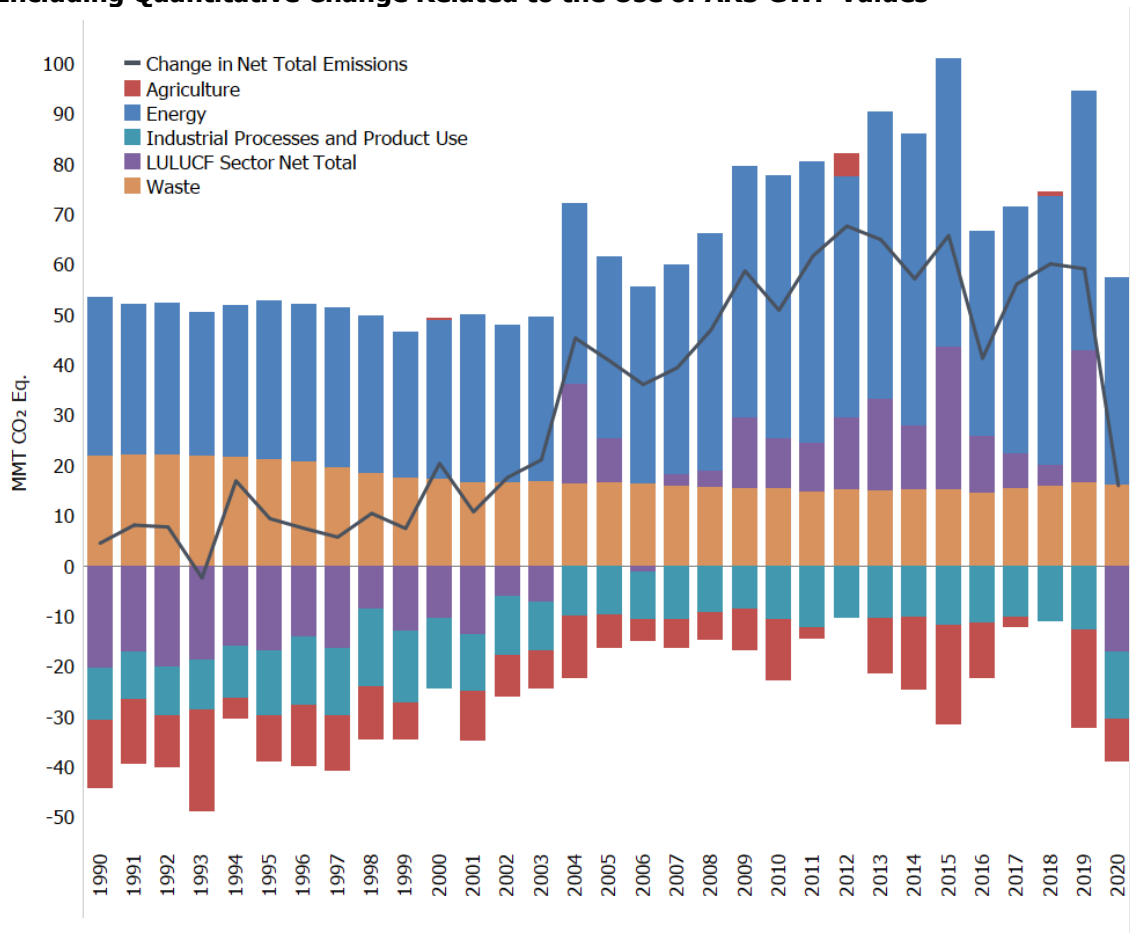

Table 9-1: Revisions to the U.S. Greenhouse Gas Emissions, Including Quantitative Change Related to the Use of AR5 GWP Values (MMT CO_2 Eq.)

Gas/Source	1990	2005	2017	2018	2019	2020	Average Annual Change
CO_2	**(1.0)**	**(5.2)**	**1.1**	**1.3**	**0.6**	**(1.3)**	**(2.4)**
Fossil Fuel Combustion	(3.0)	(4.7)	(0.8)	0.5	1.1	2.2	(2.7)
Electric Power Sector	NC	NC	NC	0.5	0.6	0.6	+
Transportation	NC	NC	0.1	0.1	0.1	0.5	(+)
Industrial	(1.3)	(0.7)	(1.4)	(0.6)	(0.2)	1.6	(0.8)
Residential	NC	NC	NC	+	+	(2.7)	+
Commercial	NC	NC	NC	+	+	1.6	+
U.S. Territories	(1.7)	(4.0)	0.5	0.5	0.6	0.6	(1.9)
Non-Energy Use of Fuels	0.2	(+)	0.2	0.6	0.8	(1.8)	0.2
Iron and Steel Production & Metallurgical Coke Production	0.5	0.3	0.6	0.6	(+)	0.9	0.3
Cement Production	NC	NC	0.2	0.2	NC	(+)	+
Natural Gas Systems	NC	NC	NC	NC	NC	NC	NC
Petrochemical Production	NC	NC	NC	NC	NC	(0.2)	NC

Petroleum Systems	(0.1)	(1.8)	(0.6)	(1.2)	0.2	(1.1)	(1.2)
Incineration of Waste	(+)	(+)	NC	NC	NC	(0.2)	(+)
Ammonia Production	1.4	1.1	1.4	0.5	0.1	0.3	1.0
Lime Production	NC	NC	NC	NC	NC	NC	NC
Other Process Uses of Carbonates	NC	NC	NC	NC	(1.4)	(1.4)	(+)
Urea Fertilization	NC	NC	(+)	(0.1)	(0.1)	(0.2)	(+)
Carbon Dioxide Consumption	NC	NC	NC	NC	NC	NC	NC
Urea Consumption for Non-Agricultural Purposes	NC	NC	(+)	0.1	0.1	(0.2)	+
Liming	+	+	(+)	(+)	(0.2)	0.5	(+)
Coal Mining	NC	NC	0.1	0.1	+	+	+
Glass Production	(+)	(+)	(+)	+	+	+	(+)
Soda Ash Production	NC	NC	NC	NC	NC	NC	NC
Ferroalloy Production	NC	NC	NC	NC	NC	NC	+
Aluminum Production	NC	NC	NC	+	(+)	NC	+
Titanium Dioxide Production	NC	NC	NC	NC	NC	(0.1)	NC
Zinc Production	NC	NC	NC	NC	NC	(+)	NC
Phosphoric Acid Production	NC	NC	NC	NC	NC	(+)	NC
Lead Production	NC	NC	NC	+	+	(+)	+
Carbide Production and Consumption	NC	NC	NC	NC	+	+	+
Abandoned Oil and Gas Wells	+	+	+	+	+	+	+
Substitution of Ozone Depleting Substances	+*	+*	+*	+*	+*	+*	+*
Magnesium Production and Processing	NC	NC	NC	NC	NC	NC	NC
Biomass and Biofuel[a]	18.5	14.7	16.2	16.2	15.8	13.9	15.8
International Bunker Fuels[b]	NC	NC	NC	NC	NC	NC	NC
CH_4[c]	**87.9**	**93.7**	**99.0**	**103.1**	**99.0**	**91.8**	**95.1**
Enteric Fermentation	19.6	20.2	21.0	21.1	21.1	21.0	20.4
Natural Gas Systems	19.6	25.9	19.8	22.6	21.5	20.5	24.3
Landfills	21.2	16.2	14.7	15.0	15.4	15.4	16.9
Manure Management	4.2	5.9	6.9	7.1	7.0	7.1	5.7
Petroleum Systems	3.5	9.6	21.4	22.0	19.5	14.2	10.9
Coal Mining	11.6	7.7	6.6	6.4	5.6	5.0	8.4
Wastewater Treatment	2.4	2.5	3.1	3.1	3.1	3.1	2.6
Rice Cultivation	1.9	2.2	1.8	1.9	1.8	1.9	1.9
Stationary Combustion	1.0	0.9	0.9	1.0	1.1	0.8	1.0
Abandoned Oil and Gas Wells	1.2	1.3	1.3	1.3	1.3	1.3	1.3
Abandoned Underground Coal Mines	0.9	0.8	0.8	0.7	0.7	0.7	0.9
Mobile Combustion	0.7	0.4	0.4	0.4	0.4	0.4	0.5
Composting	+	0.2	0.3	0.3	0.3	0.3	0.2
Field Burning of Agricultural Residues	+	0.1	0.1	0.1	0.1	0.1	+
Petrochemical Production	+	+	+	+	+	+	+
Anaerobic Digestion at Biogas Facilities	+	+	+	+	+	+	+
Ferroalloy Production	+	+	+	+	+	+	+
Carbide Production and Consumption	+	+	+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[b]	+	+	+	+	+	+	+
N_2O[c]	**(53.8)**	**(48.3)**	**(41.8)**	**(39.2)**	**(57.7)**	**(48.4)**	**(49.8)**
Agricultural Soil Management	(37.7)	(33.0)	(29.6)	(26.8)	(47.1)	(36.9)	(35.2)
Stationary Combustion	(2.8)	(3.8)	(3.1)	(3.1)	(2.7)	(2.6)	(3.3)
Wastewater Treatment	(1.8)	(2.2)	(2.6)	(2.4)	(2.1)	(2.7)	(2.2)
Manure Management	(1.5)	(1.8)	(2.1)	(2.1)	(2.2)	(2.2)	(1.8)
Mobile Combustion	(6.2)	(4.3)	(1.6)	(1.6)	(1.0)	(1.3)	(4.2)

Nitric Acid Production	(1.3)	(1.3)	(1.0)	(1.1)	(1.1)	(1.0)	(1.3)
Adipic Acid Production	(1.7)	(0.8)	(0.8)	(1.2)	(0.6)	(0.9)	(0.9)
N_2O from Product Uses	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Composting	(+)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Caprolactam, Glyoxal, and Glyoxylic Acid Production	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(+)	(0.2)
Incineration of Waste	(0.1)	(+)	(+)	(+)	(+)	(+)	(+)
Electronics Industry	+	(+)	(+)	(+)	(+)	(+)	(+)
Field Burning of Agricultural Residues	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Petroleum Systems	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Natural Gas Systems	(+)	(+)	(+)	(+)	(+)	(+)	(+)
International Bunker Fuels[b]	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
HFCs, PFCs, SF_6 and NF_3	**(8.2)**	**(8.1)**	**(9.4)**	**(9.2)**	**(9.2)**	**(9.0)**	**(9.3)**
HFCs	**(7.5)**	**(11.1)**	**(10.3)**	**(10.2)**	**(10.5)**	**(10.6)**	**(10.2)**
Substitution of Ozone Depleting Substances	+	(7.8)	(9.4)	(9.5)	(9.8)	(10.1)	(6.5)
HCFC-22 Production	(7.5)	(3.2)	(0.8)	(0.5)	(0.6)	(0.3)	(3.7)
Electronics Industry	(+)	(+)	(0.1)	(0.1)	(0.1)	(0.1)	(+)
Magnesium Production and Processing	NC	NC	(+)	(+)	(+)	(+)	(+)
PFCs	**(2.4)**	**(0.6)**	**(0.4)**	**(0.5)**	**(0.6)**	**(0.5)**	**(1.1)**
Electronics Industry	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.4)
Aluminum Production	(2.2)	(0.3)	(0.1)	(0.2)	(0.3)	(0.2)	(0.7)
Substitution of Ozone Depleting Substances	NC	(+)	(+)	(+)	(+)	(+)	(+)
Electrical Transmission and Distribution	NC	(+)	+	NC	(+)	(+)	(+)
SF_6	**1.7**	**3.7**	**1.4**	**1.4**	**1.9**	**2.1**	**2.0**
Electrical Transmission and Distribution	1.5	3.5	1.3	1.4	1.9	2.1	1.9
Magnesium Production and Processing	0.2	0.1	+	+	+	+	0.1
Electronics Industry	+	0.1	+	+	+	+	+
NF_3	**(+)**	**(0.1)**	**(+)**	**(+)**	**(+)**	**(+)**	**(+)**
Electronics Industry	(+)	(0.1)	(+)	(+)	(+)	(+)	(+)
Total Gross Emissions	**24.8**	**32.1**	**49.0**	**55.9**	**32.6**	**33.2**	**33.6**
Percent Change in Total Emissions	**0.4%**	**0.4%**	**0.8%**	**0.8%**	**0.5%**	**0.6%**	**0.5%**

NC (No Change)

+ Absolute value does not exceed 0.05 MMT CO_2 Eq. or 0.05 percent.

* Indicates a new source for the current Inventory year. Emissions from new sources are captured in net emissions and percent change totals.

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

[b] Emissions from Biomass and Biofuel Consumption are not included specifically in summing Energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry.

[c] LULUCF emissions of CH_4 and N_2O are reported separately from gross emissions totals in Table 9-2. 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; and N_2O emissions from forest soils and settlement soils.

Notes: Net change in total emissions presented without LULUCF. Parentheses indicate negative values. Totals may not sum due to independent rounding.

1

Table 9-2: Revisions to U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry, Including Quantitative Change Related to the Use of AR5 GWP Values (MMT CO_2 Eq.)

Land-Use Category	1990	2005	2017	2018	2019	2020	Average Annual Change
Forest Land Remaining Forest Land	**(46.1)**	**(21.5)**	**(25.1)**	**(28.3)**	**(6.2)**	**(41.8)**	**(30.5)**
Changes in Forest Carbon Stocks[a]	(47.5)	(27.0)	(22.4)	(27.3)	(14.5)	(39.4)	(31.9)
Non-CO_2 Emissions from Forest Fires[b]	1.4	5.5	(2.7)	(0.9)	8.3	(2.3)	1.5
N_2O Emissions from Forest Soils[c]	(+)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(+)
Non-CO_2 Emissions from Drained Organic Soils[d]	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Land Converted to Forest Land	**0.1**	**0.6**	**1.2**	**1.3**	**1.3**	**1.3**	**0.7**
Changes in Forest Carbon Stocks[e]	0.1	0.6	1.2	1.3	1.3	1.3	0.7
Cropland Remaining Cropland	**+**	**+**	**(+)**	**(+)**	**+**	**(+)**	**+**
Changes in Mineral and Organic Soil Carbon Stocks	+	+	(+)	(+)	+	(+)	+
Land Converted to Cropland	**3.0**	**2.6**	**2.3**	**2.4**	**2.3**	**2.3**	**2.6**
Changes in all Ecosystem Carbon Stocks[f]	3.0	2.6	2.3	2.4	2.3	2.3	2.6
Grassland Remaining Grassland	**1.8**	**2.3**	**1.6**	**1.6**	**1.6**	**1.5**	**2.2**
Changes in Mineral and Organic Soil Carbon Stocks	1.8	2.3	1.6	1.6	1.6	1.5	2.2
Non-CO_2 Emissions from Grassland Fires[g]	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Land Converted to Grassland	**(3.5)**	**(3.1)**	**(1.8)**	**(1.8)**	**(1.8)**	**(1.8)**	**(2.9)**
Changes in all Ecosystem Carbon Stocks[f]	(3.5)	(3.1)	(1.8)	(1.8)	(1.8)	(1.8)	(2.9)
Wetlands Remaining Wetlands	**26.8**	**25.9**	**25.9**	**25.9**	**25.9**	**26.0**	**26.1**
Changes in Organic Soil Carbon Stocks in Peatlands	NC	NC	NC	+	+	+	+
Changes in Biomass, DOM, and Soil Carbon Stocks in Coastal Wetlands	(8.4)	(7.7)	(8.8)	(8.8)	(8.8)	(8.8)	(6.8)
CH_4 Emissions from Coastal Wetlands Remaining Coastal Wetlands	12.6	11.9	13.1	13.1	13.1	13.1	11.1
N_2O Emissions from Coastal Wetlands Remaining Coastal Wetlands	(3.6)	(3.6)	(3.7)	(3.7)	(3.7)	(3.7)	(3.6)
Non-CO_2 Emissions from Peatlands Remaining Peatlands	(0.1)	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)
CH_4 Emissions from Flooded Land Remaining Flooded Land	26.4	25.5	25.5	25.5	25.5	25.5	25.7
Land Converted to Wetlands	**(3.9)**	**0.1**	**0.2**	**0.2**	**0.2**	**(+)**	**(0.9)**
Changes in Biomass, DOM, and Soil Carbon Stocks in Land Converted to Coastal Wetlands	+	+	+	+	+	NC	+
CH_4 Emissions from Land Converted to Coastal Wetlands	+	+	+	+	+	+	+
Changes in Land Converted to Flooded Land	(2.4)	+	0.1	0.1	0.1	(+)	(0.6)
CH_4 Emissions from Land Converted to Flooded Land	(1.5)	+	0.1	0.1	0.1	+	(0.3)
Settlements Remaining Settlements	**(0.2)**	**(0.3)**	**(0.2)**	**(0.1)**	**0.1**	**(7.9)**	**(0.5)**
Changes in Organic Soil Carbon Stocks	NC	NC	NC	NC	NC	NC	NC
Changes in Settlement Tree Carbon Stocks	NC	NC	0.2	0.3	0.5	(6.9)	(0.2)
Changes in Yard Trimming and Food Scrap Carbon Stocks in Landfills	NC	NC	NC	NC	NC	-0.6	(+)

N_2O Emissions from Settlement Soils[h]	(0.2)	(0.3)	(0.4)	(0.4)	(0.4)	(0.4)	(0.3)
Land Converted to Settlements	**1.7**	**2.2**	**2.9**	**3.1**	**3.2**	**3.2**	**2.3**
Changes in all Ecosystem Carbon Stocks[f]	1.7	2.2	2.9	3.1	3.2	3.2	2.3
Change in LULUCF Total Net Flux[i]	**(46.8)**	**(22.4)**	**(15.8)**	**(20.5)**	**(7.4)**	**(40.4)**	**(27.9)**
Change in LULUCF Emissions[j]	**26.5**	**31.1**	**22.9**	**24.6**	**33.8**	**23.1**	**27.0**
Change in LULUCF Sector Net Total[k]	**(20.3)**	**8.7**	**7.0**	**4.1**	**26.4**	**(17.2)**	**(0.9)**
Percent Change in LULUCF Total Net Flux	**-2.4%**	**1.1%**	**0.9%**	**0.5%**	**3.6%**	**-2.3%**	**0.0%**

NC (No Change)

+ Absolute value does not exceed 0.05 MMT CO_2 Eq. or 0.05 percent.

[a] Includes the net changes to carbon stocks stored in all forest ecosystem pools and harvested wood products.

[b] Estimates include CH_4 and N_2O emissions from fires on both Forest Land Remaining Forest Land and Land Converted to Forest Land.

[c] Estimates include N_2O emissions from N fertilizer additions on both Forest Land Remaining Forest Land and Land Converted to Forest Land.

[d] Estimates include CH_4 and N_2O emissions from drained organic soils on both Forest Land Remaining Forest Land and Land Converted to Forest Land.

[e] Includes the net changes to carbon stocks stored in all forest ecosystem pools.

[f] Includes changes in mineral and organic soil carbon stocks for all land use conversions to cropland, grassland, and settlements, respectively. Also includes aboveground/belowground biomass, dead wood, and litter carbon stock changes for conversion of forest land to cropland, grassland, and settlements, respectively.

[g] Estimates include CH_4 and N_2O emissions from fires on both Grassland Remaining Grassland and Land Converted to Grassland.

[h] Estimates include N_2O emissions from N fertilizer additions on both Settlements Remaining Settlements and Land Converted to Settlements because it is not possible to separate the activity data at this time.

[i] LULUCF Carbon Stock Change includes any C stock gains and losses from all land use and land use conversion categories.

[j] 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; and N_2O emissions from forest soils and settlement soils.

[k] The LULUCF Sector Net Total is the net sum of all LULUCF CH_4 and N_2O emissions to the atmosphere plus LULUCF net carbon stock changes.

Notes: Parentheses indicate negative values. Totals may not sum due to independent rounding.

Table 9-3: Revisions to U.S. Greenhouse Gas Emissions, Excluding Quantitative Change Related to the Use of AR5 GWP Values (MMT CO_2 Eq.)

Gas/Source	1990	2005	2017	2018	2019	2020	Average Annual Change
CO_2	**(1.0)**	**(5.2)**	**1.1**	**1.3**	**0.6**	**(1.3)**	**(2.4)**
Fossil Fuel Combustion	(3.0)	(4.7)	(0.8)	0.5	1.1	2.2	(2.5)
Electric Power Sector	351.0	541.5	(47.9)	(59.3)	(207.0)	(132.5)	354.8
Transportation	(351.0)	(541.5)	48.1	60.0	207.8	133.5	(354.8)
Industrial	(1.3)	(0.7)	(1.4)	(0.6)	(0.2)	1.6	(0.8)
Residential	NC	NC	NC	+	+	(2.7)	(0.1)
Commercial	NC	NC	NC	+	+	1.6	0.1
U.S. Territories	(1.7)	(4.0)	0.5	0.5	0.6	0.6	(1.8)
Non-Energy Use of Fuels	0.2	(+)	0.2	0.6	0.8	(1.8)	0.2
Iron and Steel Production & Metallurgical Coke Production	NC	NC	0.2	0.2	NC	(+)	+
Cement Production	NC	NC	NC	NC	NC	NC	NC
Natural Gas Systems	0.5	0.3	0.6	0.6	(+)	0.9	0.4
Petrochemical Production	NC	NC	NC	NC	NC	(0.2)	(+)
Petroleum Systems	(0.1)	(1.8)	(0.6)	(1.2)	0.2	(1.1)	(1.2)

Incineration of Waste	(+)	(+)	NC	NC	NC	(0.2)	(+)
Ammonia Production	1.4	1.1	1.4	0.5	0.1	0.3	1.0
Lime Production	NC	NC	NC	NC	NC	NC	NC
Other Process Uses of Carbonates	NC	NC	NC	NC	(1.4)	(1.4)	(0.1)
Urea Fertilization	NC	NC	(+)	(0.1)	(0.1)	(0.2)	(+)
Carbon Dioxide Consumption	NC	NC	NC	NC	NC	NC	NC
Urea Consumption for Non-Agricultural Purposes	NC	NC	(+)	0.1	0.1	(0.2)	(+)
Liming	+	+	(+)	(+)	(0.2)	0.5	+
Coal Mining	NC	NC	0.1	0.1	+	+	+
Glass Production	(+)	(+)	(+)	+	+	+	(+)
Soda Ash Production	NC	NC	NC	NC	NC	NC	NC
Ferroalloy Production	NC	NC	NC	NC	NC	NC	+
Aluminum Production	NC	NC	NC	+	(+)	NC	+
Titanium Dioxide Production	NC	NC	NC	NC	NC	(0.1)	(+)
Zinc Production	NC	NC	NC	NC	NC	(+)	(+)
Phosphoric Acid Production	NC	NC	NC	NC	NC	(+)	(+)
Lead Production	NC	NC	NC	+	+	(+)	+
Carbide Production and Consumption	NC	NC	NC	NC	+	+	+
Abandoned Oil and Gas Wells	+	+	+	+	+	+	+
Substitution of Ozone Depleting Substances	NC*	NC*	NC*	NC*	NC*	NC*	NC*
Magnesium Production and Processing	(+)	(+)	+	+	+	+	+
Biomass and Biofuel Consumption[a]	18.5	14.7	16.2	16.2	15.8	13.9	15.7
International Bunker Fuels[b]	NC	NC	NC	NC	NC	NC	NC
CH_4[c]	**(5.8)**	**10.0**	**19.4**	**22.5**	**18.7**	**13.8**	**9.4**
Enteric Fermentation	NC	NC	NC	NC	NC	NC	NC
Natural Gas Systems	(3.9)	4.6	(0.1)	2.0	0.8	0.7	2.6
Landfills	NC	0.4	1.6	1.6	1.7	2.3	0.4
Manure Management	NC	NC	NC	NC	NC	NC	+
Petroleum Systems	(2.2)	4.6	16.5	17.4	14.7	9.4	5.7
Coal Mining	NC	+	+	+	(0.1)	+	(+)
Wastewater Treatment	(+)	0.1	0.8	0.9	0.9	0.9	0.3
Rice Cultivation	NC	NC	NC	NC	NC	(+)	(+)
Stationary Combustion	(+)	(+)	+	+	+	(0.1)	(+)
Abandoned Oil and Gas Wells	0.4	0.4	0.5	0.5	0.5	0.5	0.4
Abandoned Underground Coal Mines	NC	NC	NC	NC	NC	+	+
Mobile Combustion	(0.1)	(0.1)	0.1	0.1	0.1	0.1	+
Composting	NC	NC	NC	NC	(+)	+	+
Field Burning of Agricultural Residues	NC	NC	NC	NC	NC	NC	(+)
Petrochemical Production	NC	NC	NC	NC	NC	(+)	(+)
Anaerobic Digestion at Biogas Facilities	NC	NC	NC	NC	NC	NC	NC
Ferroalloy Production	NC	NC	NC	NC	NC	NC	+
Carbide Production and Consumption	NC	NC	NC	NC	NC	NC	+
Iron and Steel Production & Metallurgical Coke Production	NC	NC	NC	NC	NC	(+)	(+)
Incineration of Waste	NC	NC	NC	NC	NC	(+)	(+)
International Bunker Fuels[b]	NC	NC	NC	NC	NC	NC	NC
N_2O[c]	**(3.9)**	**2.0**	**7.4**	**11.5**	**(7.1)**	**(1.2)**	**0.5**
Agricultural Soil Management	(2.7)	1.7	6.8	10.7	(8.9)	(1.9)	0.2
Stationary Combustion	(+)	(+)	+	+	+	(+)	(+)
Wastewater Treatment	(+)	(+)	+	0.2	0.5	(+)	+
Manure Management	NC	NC	NC	NC	NC	NC	NC
Mobile Combustion	(1.2)	0.2	0.6	0.5	1.2	0.7	0.3
Nitric Acid Production	NC	NC	NC	NC	NC	NC	NC

Adipic Acid Production	NC	NC	NC	NC	NC	NC	NC
N_2O from Product Uses	NC	NC	NC	NC	NC	NC	NC
Composting	NC	NC	NC	NC	(+)	+	+
Caprolactam, Glyoxal, and Glyoxylic Acid Production	NC	NC	NC	NC	NC	0.1	+
Incineration of Waste	NC	NC	NC	NC	NC	(+)	(+)
Electronics Industry	+	+	+	+	+	(+)	+
Field Burning of Agricultural Residues	NC	NC	NC	NC	NC	NC	(+)
Petroleum Systems	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Natural Gas Systems	+	+	(+)	(+)	(+)	(+)	+
International Bunker Fuels[b]	NC	NC	NC	NC	NC	NC	NC
HFCs, PFCs, SF_6 and NF_3	**0.8**	**3.2**	**1.1**	**1.2**	**1.5**	**1.9**	**1.5**
HFCs	**+**	**(0.1)**	**(0.1)**	**(+)**	**(+)**	**+**	**(0.1)**
Substitution of Ozone Depleting Substances	NC	(0.1)	(0.1)	(+)	(+)	(+)	(0.1)
HCFC-22 Production	NC	NC	NC	NC	NC	NC	NC
Electronics Industry	+	+	+	+	+	+	+
Magnesium Production and Processing	NC	NC	NC	NC	+	NC	+
PFCs	**+**	**(+)**	**+**	**(0.1)**	**(0.2)**	**(0.1)**	**(+)**
Electronics Industry	+	(+)	+	(+)	+	(+)	(+)
Aluminum Production	NC	+	+	(0.1)	(0.2)	(0.1)	(+)
Substitution of Ozone Depleting Substances	NC	NC	NC	NC	NC	NC	NC
Electrical Transmission and Distribution	NC	(+)	+	NC	NC	NC	(+)
SF_6	**0.8**	**3.3**	**1.2**	**1.3**	**1.7**	**1.9**	**1.6**
Electrical Transmission and Distribution	0.8	3.2	1.2	1.3	1.7	1.9	1.6
Magnesium Production and Processing	4.8	2.1	0.3	0.3	0.1	0.1	2.3
Electronics Industry	(4.8)	(2.0)	(0.3)	(0.3)	(0.1)	(0.1)	(2.3)
NF_3	**NC**	**(+)**	**+**	**(+)**	**(+)**	**(+)**	**(+)**
Electronics Industry	NC	(+)	+	(+)	(+)	(+)	(+)
Total Gross Emissions	**(10.0)**	**9.9**	**29.1**	**36.5**	**13.8**	**13.1**	**9.1**
Percentage Change in Total Emissions	**-0.2%**	**0.1%**	**0.4%**	**0.5%**	**0.2%**	**0.2%**	**0.1%**

NC (No Change)

+ Absolute value does not exceed 0.05 MMT CO_2 Eq. or 0.05 percent.

* Indicates a new source for the current Inventory year. Emissions from new sources are captured in net emissions and percent change totals.

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

[b] Emissions from Biomass and Biofuel Consumption are not included specifically in summing Energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry.

[c] LULUCF emissions of CH_4 and N_2O are reported separately from gross emissions totals in Table 9-2. 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; and N_2O emissions from forest soils and settlement soils.

Notes: Net change in total emissions presented without LULUCF. Parentheses indicate negative values. Totals may not sum due to independent rounding.

Table 9-4: Revisions to U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry, Excluding Quantitative Change Related to the Use of AR5 GWP Values (MMT CO_2 Eq.)

Land-Use Category	1990	2005	2015	2016	2017	2018	Average Annual Change
Forest Land Remaining Forest Land	**(46.1)**	**(21.5)**	**(25.1)**	**(28.3)**	**(6.2)**	**(41.8)**	**(30.5)**
Changes in Forest Carbon Stocks[a]	(47.5)	(27.0)	(22.4)	(27.3)	(14.5)	(39.4)	(31.9)
Non-CO_2 Emissions from Forest Fires[b]	1.4	5.5	(2.7)	(0.9)	8.3	(2.3)	1.5

N_2O Emissions from Forest Soils[c]	(+)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(+)
Non-CO_2 Emissions from Drained Organic Soils[d]	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Land Converted to Forest Land	**0.1**	**0.6**	**1.2**	**1.3**	**1.3**	**1.3**	**0.7**
Changes in Forest Carbon Stocks[e]	0.1	0.6	1.2	1.3	1.3	1.3	0.7
Cropland Remaining Cropland	**+**	**+**	**(+)**	**(+)**	**+**	**(+)**	**+**
Changes in Mineral and Organic Soil Carbon Stocks	+	+	(+)	(+)	+	(+)	+
Land Converted to Cropland	**3.0**	**2.6**	**2.3**	**2.4**	**2.3**	**2.3**	**2.6**
Changes in all Ecosystem Carbon Stocks[f]	3.0	2.6	2.3	2.4	2.3	2.3	2.6
Grassland Remaining Grassland	**1.8**	**2.3**	**1.6**	**1.6**	**1.6**	**1.5**	**2.2**
Changes in Mineral and Organic Soil Carbon Stocks	1.8	2.3	1.6	1.6	1.6	1.5	2.2
Non-CO_2 Emissions from Grassland Fires[g]	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Land Converted to Grassland	**(3.5)**	**(3.1)**	**(1.8)**	**(1.8)**	**(1.8)**	**(1.8)**	**(2.9)**
Changes in all Ecosystem Carbon Stocks[f]	(3.5)	(3.1)	(1.8)	(1.8)	(1.8)	(1.8)	(2.9)
Wetlands Remaining Wetlands	**26.8**	**25.9**	**25.9**	**25.9**	**25.9**	**26.0**	**26.1**
Changes in Organic Soil Carbon Stocks in Peatlands	NC	NC	NC	+	+	+	+
Changes in Biomass, DOM, and Soil Carbon Stocks in Coastal Wetlands	+	+	+	+	+	+	+
CH_4 Emissions from Coastal Wetlands Remaining Coastal Wetlands	+	(0.1)	+	+	+	+	+
N_2O Emissions from Coastal Wetlands Remaining Coastal Wetlands	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Non-CO_2 Emissions from Peatlands Remaining Peatlands	(+)	(+)	(+)	(+)	(+)	(+)	(+)
CH_4 Emissions from Flooded Land Remaining Flooded Land	26.4	25.5	25.5	25.5	25.5	25.5	25.7
Land Converted to Wetlands	**(3.9)**	**0.1**	**0.2**	**0.2**	**0.2**	**(+)**	**(0.9)**
Changes in Biomass, DOM, and Soil Carbon Stocks in Land Converted to Coastal Wetlands	+	+	+	+	+	NC	+
CH_4 Emissions from Land Converted to Coastal Wetlands	+	+	+	+	+	+	+
Changes in Land Converted to Flooded Land	(2.4)	+	0.1	0.1	0.1	(+)	(0.6)
CH_4 Emissions from Land Converted to Flooded Land	(1.5)	+	0.1	0.1	0.1	+	(0.3)
Settlements Remaining Settlements	**0.4**	**0.6**	**0.5**	**0.6**	**0.8**	**(7.2)**	**0.3**
Changes in Organic Soil Carbon Stocks	NC	NC	NC	NC	NC	NC	NC
Changes in Settlement Tree Carbon Stocks	NC	NC	0.2	0.3	0.5	(6.9)	(0.2)
Changes in Yard Trimming and Food Scrap Carbon Stocks in Landfills	NC	NC	NC	NC	NC	-0.6	(+)
N_2O Emissions from Settlement Soils[h]	0.4	0.6	0.3	0.3	0.3	0.3	0.5
Land Converted to Settlements	**1.7**	**2.2**	**2.9**	**3.1**	**3.2**	**3.2**	**2.3**
Changes in all Ecosystem Carbon Stocks[f]	1.7	2.2	2.9	3.1	3.2	3.2	2.3
Change in LULUCF Total Net Flux[i]	**(46.8)**	**(22.4)**	**(15.8)**	**(20.5)**	**(7.4)**	**(40.4)**	**(27.9)**
Change in LULUCF Emissions[j]	**24.6**	**30.7**	**22.4**	**23.8**	**32.3**	**23.4**	**25.9**
Change in LULUCF Sector Net Total[k]	**(22.2)**	**8.3**	**6.6**	**3.3**	**24.9**	**(17.0)**	**(2.0)**
Percent Change in LULUCF Total Net Flux	**-2.6%**	**1.1%**	**0.4%**	**0.4%**	**3.4%**	**-2.2%**	**-0.1%**

NC (No Change)

+ Absolute value does not exceed 0.05 MMT CO_2 Eq. or 0.05 percent.

[a] Includes the net changes to carbon stocks stored in all forest ecosystem pools and harvested wood products.

[b] Estimates include CH_4 and N_2O emissions from fires on both Forest Land Remaining Forest Land and Land Converted to Forest Land.

[c] Estimates include N_2O emissions from N fertilizer additions on both Forest Land Remaining Forest Land and Land Converted to Forest Land.

[d] Estimates include CH_4 and N_2O emissions from drained organic soils on both Forest Land Remaining Forest Land and Land Converted to Forest Land.

[e] Includes the net changes to carbon stocks stored in all forest ecosystem pools.

[f] Includes changes in mineral and organic soil carbon stocks for all land use conversions to cropland, grassland, and settlements, respectively. Also includes aboveground/belowground biomass, dead wood, and litter carbon stock changes for conversion of forest land to cropland, grassland, and settlements, respectively.

[g] Estimates include CH_4 and N_2O emissions from fires on both Grassland Remaining Grassland and Land Converted to Grassland.

[h] Estimates include N_2O emissions from N fertilizer additions on both Settlements Remaining Settlements and Land Converted to Settlements because it is not possible to separate the activity data at this time.

[i] LULUCF Carbon Stock Change includes any C stock gains and losses from all land use and land use conversion categories.

[j] 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; and N_2O emissions from forest soils and settlement soils.

[k] The LULUCF Sector Net Total is the net sum of all LULUCF CH_4 and N_2O emissions to the atmosphere plus LULUCF net carbon stock changes.

Notes: Parentheses indicate negative values. Totals may not sum due to independent rounding.

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