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, 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 states, "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."

The results of all methodological changes and historical data updates made in the current Inventory are presented in Table 9-1 and Table 9-2. To understand the details of any specific recalculation or methodological improvement, see the *Recalculations Discussion* within each source/sink categories' section found in Chapters 3 through 7 of this report and a discussion of Inventory improvements in Annex 8. Table 9-1 summarizes the quantitative effect of all changes on U.S. greenhouse gas emissions in the Energy, IPPU, Agriculture, and Waste sectors, while Table 9-2 summarizes the quantitative effect of changes on annual net fluxes from LULUCF. Both tables present results relative to the previously published Inventory (i.e., the 1990 to 2015 report) in units of million metric tons of carbon dioxide equivalent (MMT CO_2 Eq.).

In general, when methodological changes have been implemented, the previous Inventory's time series (i.e., 1990 to 2015) will be recalculated to reflect the change, per guidance in IPCC (2006). Changes in historical data are generally the result of changes in statistical data supplied by other agencies, and do not necessarily impact the entire time series.

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.

- *Petroleum Systems (CH_4).* Updates were made to exploration and production segment methodologies for the Inventory, including revising activity and CH_4 emissions data for associated gas venting and flaring, miscellaneous production flaring, and well testing. The combined impact of revisions to 2015 petroleum systems CH_4 emissions, compared to the previous Inventory, is a decrease from 39.9 to 38.1 MMT CO_2 Eq. (1.8 MMT CO_2 Eq., or 4.5 percent). The CH_4 emissions estimate decrease was primarily due to recalculations related to associated gas venting and flaring which were updated to use a basin-level approach, and has the largest impact on years prior to 2013. The recalculations resulted in an average annual decrease in CH_4 emissions of 13.4 MMT CO_2 Eq. (28 percent), across the 1990 through 2015 time series, relative to the previous Inventory.
- *Natural Gas Systems (CO_2).* Updates were made to exploration through transmission and storage segments, including to calculate activity and emission factors for well testing and non-hydraulically fractured completions from EPA's GHGRP data, recalculate production segment major equipment activity factors using updated GHGRP data, and calculate new CO_2 emission factors for several sources throughout segments using GHGRP data. The combined impact of revisions to 2015 natural gas sector CO_2 emissions, compared to the previous Inventory, is a decrease from 42.4 to 24.9 MMT CO_2 (17.5 MMT CO_2, or 41 percent). The decreased estimate results primarily from recalculations related to the reallocation of CO_2 from flaring to petroleum systems from natural gas systems. Previously, data were not available to

disaggregate flared emissions between natural gas and petroleum. The recalculations resulted in an average annual decrease in CO_2 emissions of 10.5 MMT CO_2 Eq. (29.5) percent relative to the previous Inventory.

- *Petroleum Systems (CO_2).* Updates were made to exploration and production segment methodologies for the Inventory, including revising activity and CO_2 emissions data for associated gas venting and flaring, miscellaneous production flaring, and well testing. Production segment CO_2 emissions data were also revised for oil tanks, pneumatic controllers, and chemical injection pumps. The combined impact of revisions to 2015 petroleum systems CO_2 emissions, compared to the previous Inventory, is an increase from 3.6 to 28.8 MMT CO_2 (25.2 MMT CO_2, or by a factor of 7). The CO_2 emissions estimate increase was primarily due to recalculations related to the reallocation of CO_2 from flaring to petroleum systems from natural gas systems. Previously, data were not available to disaggregate flared emissions between natural gas systems and petroleum systems. The largest sources of CO_2 from flaring are associated gas flaring, tanks with flares, and miscellaneous production flaring. The recalculations resulted in an average annual increase in CO_2 emissions of 9.1 MMT CO_2 Eq. (240 percent) relative to the previous Inventory.
- *Mobile Combustion (CH_4).* Updates were made to the on-road, non-road and alternative fuel CH_4 emissions calculations for the current Inventory, resulting in both increases and decreases to different source categories. Decreases in on-road gasoline CH_4 emissions were offset by large increases in alternative fuel and non-road CH_4 emissions. New onroad CH_4 emission factors were calculated based on the ratio of non-methane organic gas (NMOG) emission standards for newer vehicles. In addition, new non-road emission factors were developed from the updated 2006 IPCC Tier 3 guidance and EPA's MOVES2014a model. New emission factors for alternative fuel vehicles were estimated using the newest version of GREET (2016). In addition, changes were made to the historic allocation of gasoline to on-road and non-road applications. These changes collectively resulted in an average annual increase in CH_4 emissions of 5.8 MMT CO_2 Eq. (166.8 percent) relative to the previous Inventory.
- *Natural Gas Systems (CH_4)* Updates were made to exploration through transmission and storage segments, including to calculate activity and emission factors for well testing and non-hydraulically fractured completions from EPA's GHGRP data, recalculate production segment major equipment activity factors using updated GHGRP data, and calculate new CO_2 emission factors for several sources throughout segments using GHGRP data. The combined impact of revisions to 2015 natural gas sector CH_4 emissions, compared to the previous Inventory, is an increase from 162.4 to 166.3 MMT CO_2 Eq. (3.9 MMT CO_2 Eq., or 2.4 percent). These changes resulted in an average annual increase in CH_4 emissions of 5.1 MMT CO_2 Eq. (3.1 percent) relative to the previous Inventory.
- *Information Item: Wood Biomass, Ethanol, and Biodiesel Consumption (CO_2).* EIA updated wood biomass and biofuels consumption statistics across the time series relative to the previous Inventory (EIA 2018a). EIA revised 2010 through 2015 wood energy consumption in the industrial sector, and 2014 through 2015 wood energy consumption in the residential and commercial sectors. Additionally, EIA revised sector allocations of ethanol in 2015, resulting in a shift of ethanol consumption from the industrial and commercial sectors to the transportation sector. These revisions to wood energy consumption resulted in an average annual increase in CO_2 emissions of 3.4 MMT CO_2 Eq. (1.2 percent) relative to the previous Inventory. Note, as indicated in Table 9-1, these emissions are not included in totals. CO_2 emissions from wood biomass and biofuel consumption are not included specifically in summing energy sector totals and are instead included in net carbon fluxes from changes in biogenic carbon reservoirs in the estimates for Land Use, Land-Use Change, and Forestry.
- *Mobile Combustion (N_2O).* Updates were made to the on-road, non-road and alternative fuel N_2O emissions calculations for the current Inventory resulting in both increases and decreases to different source categories. Decreases in on-road gasoline N_2O emissions were offset by large increases in alternative fuel and non-road N_2O emissions. New emission factors for N_2O emissions were developed for on-road vehicles based on an EPA regression analysis of the relationship between NO_x and N_2O. In addition, new non-road emissions factors were developed from the updated 2006 IPCC Tier 3 guidance and EPA's MOVES2014a model. N_2O emission factors were calculated using NONROAD activity and emission factors by fuel type from the European Environment Agency. New emission factors for alternative fuel vehicles were estimated using the newest version of GREET (2016). In addition, changes were made to the historic allocation of gasoline to on-road and non-road applications. These changes resulted in an average annual increase in N_2O emissions of 2.5 MMT CO_2 Eq. (9.2 percent) relative to the previous Inventory.

- *Fossil Fuel Combustion-Transportation (CO_2).* Changes were made to the historic allocation of gasoline to on-road and non-road applications. In 2016, the Federal Highway Administration (FHWA) changed its methods for estimating the share of gasoline used in on-road and non-road applications. Among other updates, FHWA included lawn and garden equipment as well as off-road recreational equipment in its estimates of non-road gasoline consumption for the first time. This change created a time-series inconsistency between the data reported for years 2015 and 2016 and previous years. To create a more consistent time series of motor gasoline consumption and emissions data for the current Inventory, the historical time series was modified. Specifically, the lawn, garden, and recreational vehicle gasoline consumption from EPA's NONROAD model is subtracted from the highway motor gasoline consumption from FHWA Table MF-21 when determining the total highway motor gasoline consumption for years 1990 through 2014. This resulted in a decrease of gasoline use and emissions in the transportation sector and an increase in the commercial and industrial sectors. These changes resulted in an average annual shift in CO_2 emissions of 27.3 MMT CO_2 Eq. (1.6 percent) relative to the previous Inventory.

Finally, in addition to the more significant methodological updates noted above, the Inventory includes new categories not included in the previous Inventory that improve completeness of the national estimates. Specifically, the inclusion of CO_2 and CH_4 emissions from Abandoned Oil and Gas Wells and N_2O emissions from Caprolactam Production, etc.

Table 9-1: Revisions to U.S. Greenhouse Gas Emissions (MMT CO_2 Eq.)

Gas/Source	1990	2005	2012	2013	2014	2015	Average Annual Change
CO_2	**(1.8)**	**0.2**	**4.6**	**5.6**	**3.3**	**9.4**	**(1.2)**
Fossil Fuel Combustion	+	+	(0.3)	0.4	(2.0)	(0.5)	(0.1)
Electric Power Sector	*NC*	*NC*	*NC*	*NC*	*NC*	+	+
Transportation	*(26.2)*	*(31.3)*	*(34.9)*	*(35.4)*	*(25.7)*	*(0.9)*	*(27.3)*
Industrial	*16.4*	*27.7*	*30.0*	*31.0*	*18.9*	*4.0*	*22.9*
Residential	*NC*	*NC*	+	*0.1*	*(0.1)*	*(2.8)*	*(0.1)*
Commercial	*9.8*	*3.6*	*4.6*	*4.7*	*4.9*	*(0.8)*	*4.4*
U.S. Territories	*NC*	*NC*	*NC*	*NC*	*NC*	*NC*	*NC*
Non-Energy Use of Fuels	2.0	+	1.2	(0.2)	(0.1)	0.1	0.2
Natural Gas Systems	(7.9)	(7.6)	(11.9)	(13.6)	(17.0)	(17.5)	(10.5)
Cement Production	NC	NC	NC	NC	NC	NC	NC
Lime Production	NC	NC	NC	NC	NC	NC	NC
Other Process Uses of Carbonates	1.4	1.3	1.1	1.1	1.1	1.1	1.3
Glass Production	NC	NC	NC	NC	NC	NC	NC
Soda Ash Production	(1.4)	(1.3)	(1.1)	(1.1)	(1.1)	(1.1)	(1.3)
Carbon Dioxide Consumption	NC	NC	NC	NC	NC	0.2	+
Incineration of Waste	NC	NC	+	+	+	+	+
Titanium Dioxide Production	NC	NC	NC	NC	NC	NC	NC
Aluminum Production	NC	NC	NC	NC	NC	NC	NC
Iron and Steel Production & Metallurgical Coke Production	0.1	0.2	0.2	0.1	(0.3)	(1.1)	0.1
Ferroalloy Production	NC	NC	NC	NC	NC	NC	NC
Ammonia Production	NC	NC	NC	NC	NC	0.1	+
Urea Consumption for Non-Agricultural Purposes	NC	NC	+	0.1	0.2	3.0	0.1
Phosphoric Acid Production	NC	NC	NC	NC	NC	NC	NC
Petrochemical Production	(0.1)	(0.2)	NC	NC	NC	NC	(0.1)
Silicon Carbide Production and Consumption	NC	NC	NC	NC	NC	NC	NC
Lead Production	NC	NC	NC	NC	NC	NC	NC
Zinc Production	NC	NC	NC	NC	NC	+	+
Petroleum Systems	4.1	7.8	15.4	18.9	22.8	25.2	9.1
Abandoned Oil and Gas Wells	NC*	NC*	NC*	NC*	NC*	NC*	NC*
Magnesium Production and Processing	NC	NC	NC	NC	NC	NC	NC
Liming	NC	NC	NC	NC	NC	+	+
Urea Fertilization	NC	NC	+	(0.1)	(0.2)	(0.1)	+
International Bunker Fuels[b]	*NC*	*NC*	*NC*	*NC*	*0.2*	*0.1*	+
Wood Biomass, Ethanol, and Biodiesel Consumption[a]	*NC*	*NC*	*11.5*	*16.6*	*17.2*	*18.7*	*3.4*

CH_4	**(0.9)**	**7.7**	**(3.6)**	**3.8**	**4.8**	**9.7**	**3.6**
Stationary Combustion	0.1	0.4	0.8	0.8	0.8	0.9	0.4
Mobile Combustion	7.1	6.5	2.9	2.6	2.2	1.8	5.8
Coal Mining	NC	NC	NC	NC	(0.3)	0.3	+
Abandoned Underground Coal Mines	NC	NC	NC	NC	NC	NC	NC
Natural Gas Systems	1.1	9.4	3.4	4.6	1.8	3.9	5.1
Petroleum Systems	(15.7)	(13.9)	(13.8)	(7.9)	(4.5)	(1.8)	(13.4)
Abandoned Oil and Gas Wells	NC*	NC*	NC*	NC*	NC*	NC*	NC*
Petrochemical Production	NC	NC	NC	NC	NC	NC	NC
Silicon Carbide Production and Consumption	NC	NC	NC	NC	NC	NC	NC
Iron and Steel Production & Metallurgical Coke Production	NC	NC	NC	NC	NC	NC	NC
Ferroalloy Production	NC	NC	NC	NC	NC	NC	NC
Enteric Fermentation	NC	NC	NC	NC	NC	NC	NC
Manure Management	NC	NC	NC	NC	+	NC	+
Rice Cultivation	NC	NC	NC	0.2	1.4	1.1	0.1
Field Burning of Agricultural Residues	NC	NC	NC	NC	NC	NC	NC
Landfills	NC	(1.6)	(3.8)	(3.5)	(3.8)	(4.0)	(1.2)
Wastewater Treatment	+	(0.2)	+	+	0.2	0.3	(0.1)
Composting	NC	NC	NC	NC	NC	NC	NC
Incineration of Waste	NC	NC	NC	NC	NC	NC	NC
International Bunker Fuels[b]	*NC*	*NC*	*NC*	*NC*	*NC*	*NC*	*NC*
N_2O	**(4.8)**	**(3.9)**	**(5.0)**	**27.7**	**25.7**	**44.8**	**0.1**
Stationary Combustion	(0.8)	(2.8)	(4.5)	(4.2)	(4.3)	(5.0)	(2.3)
Mobile Combustion	0.5	3.1	3.9	4.0	4.0	4.2	2.5
Adipic Acid Production	NC	NC	NC	NC	NC	+	+
Nitric Acid Production	NC	NC	+	NC	NC	+	+
Manure Management	NC	NC	NC	NC	NC	NC	NC
Agricultural Soil Management	(6.1)	(6.3)	(6.2)	26.1	24.0	43.7	(2.0)
Field Burning of Agricultural Residues	NC	NC	NC	NC	NC	NC	NC
Wastewater Treatment	NC	NC	(0.2)	(0.2)	(0.1)	(0.1)	+
N_2O from Product Uses	NC	NC	NC	NC	NC	NC	NC
Caprolactam, Glyoxal, and Glyoxylic Acid Production	NC*	NC*	NC*	NC*	NC*	NC*	NC*
Incineration of Waste	NC	NC	NC	NC	NC	NC	NC
Composting	NC	NC	NC	NC	NC	NC	NC
Semiconductor Manufacture	NC	NC	+	+	+	+	+
International Bunker Fuels[b]	NC	NC	NC	NC	+	+	+
HFCs	**NC**	**3.0**	**(5.4)**	**(7.9)**	**(10.0)**	**(12.4)**	**(0.5)**
Substitution of Ozone Depleting Substances[d]	NC	3.0	(5.4)	(7.9)	(10.0)	(12.4)	(0.5)
HCFC-22 Production	NC	NC	NC	NC	NC	NC	NC
Semiconductor Manufacture	NC	+	+	+	+	+	+
Magnesium Production and Processing	NC	NC	NC	NC	NC	NC	NC
PFCs	**NC**	**0.1**	**(0.1)**	**+**	**(0.1)**	**(0.1)**	**+**
Aluminum Production	NC	NC	NC	NC	NC	NC	NC
Semiconductor Manufacture	NC	0.1	(0.1)	+	(0.1)	(0.1)	+
Substitution of Ozone Depleting Substances[d]	NC	NC	NC	NC	NC	NC	NC
SF_6	**+**	**0.1**	**(0.2)**	**(0.1)**	**(0.2)**	**0.1**	**+**
Electrical Transmission and Distribution	+	0.1	(0.1)	(0.1)	(0.2)	0.1	+
Semiconductor Manufacture	NC	+	+	+	+	+	+
Magnesium Production and Processing	NC	NC	NC	NC	+	+	+
NF_3	**NC**	**+**	**+**	**+**	**+**	**+**	**+**
Semiconductor Manufacture	NC	+	+	+	+	+	+
Net Emissions (Sources and Sinks)	(7.4)	7.0	(9.5)	29.1	23.5	51.5	
Percent Change	-0.1%	0.1%	-0.1%	0.4%	0.3%	0.8%	

Note: Net change in total emissions presented without LULUCF.
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.
[a] Not included in emissions total.
[b] Sinks are only included in net emissions total.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values.

Table 9-2: Revisions to U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry (MMT CO_2 Eq.)

Land Use Category	1990	2005	2012	2013	2014	2015	Average Annual Change
Forest Land Remaining Forest Land	**+**	**+**	**+**	**+**	**(0.1)**	**18.6**	**0.7**
Changes in Forest Carbon Stocks[a]	+	0.1	+	+	+	+	+
Non-CO_2 Emissions from Forest Fires	+	+	+	+	(0.1)	18.6	0.7
N_2O Emissions from Forest Soils[b]	NC	NC	NC	NC	NC	NC	NC
Non-CO_2 Emissions from Drained Organic Soils	+	+	+	+	+	+	+
Land Converted to Forest Land	**NC**	**(0.2)**	**0.3**	**0.3**	**0.2**	**0.2**	**+**
Changes in Forest Carbon Stocks[c]	NC	(0.2)	0.3	0.3	0.2	0.2	+
Cropland Remaining Cropland	**NC**	**NC**	**NC**	**8.2**	**6.7**	**11.7**	**1.0**
Changes in Mineral and Organic Soil Carbon Stocks	NC	NC	NC	8.2	6.7	11.7	1.0
Land Converted to Cropland	**NC**	**NC**	**NC**	**0.6**	**0.5**	**0.4**	**0.1**
Changes in all Ecosystem Carbon Stocks[d]	NC	NC	NC	0.6	0.5	0.4	0.1
Grassland Remaining Grassland	NC	NC	NC	16.7	12.8	30.3	2.3
Changes in Mineral and Organic Soil Carbon Stocks	NC	NC	NC	16.7	12.8	30.5	2.3
Non-CO_2 Emissions from Grassland Fires	NC	NC	NC	NC	NC	(0.2)	+
Land Converted to Grassland	**NC**	**NC**	**NC**	**1.4**	**1.0**	**2.9**	**0.2**
Changes in all Ecosystem Carbon Stocks[d]	NC	NC	NC	1.4	1.0	2.9	0.2
Wetlands Remaining Wetlands	**NC**	**NC**	**NC**	**NC**	**NC**	**NC**	**NC**
Changes in Organic Soil Carbon Stocks in Peatlands	NC*	NC*	NC*	NC*	NC*	NC*	NC*
Changes in Mineral and Organic Soil Carbon Stocks in Coastal Wetlands	(1.1)	(1.1)	(0.8)	(0.8)	(0.8)	(0.8)	(1.0)
CH_4 Emissions from Coastal Wetlands Remaining Coastal Wetlands	NC	NC	NC	NC	NC	NC	NC
N_2O Emissions from Coastal Wetlands Remaining Coastal Wetlands	NC	NC	NC	NC	NC	NC	NC
Non-CO_2 Emissions from Peatlands Remaining Peatlands	NC	NC	NC	NC	NC	NC	NC
Land Converted to Wetlands	**+**	**+**	**+**	**+**	**+**	**+**	**+**
Changes in Mineral and Organic Soil Carbon Stocks[e]	+	+	+	+	+	+	+
CH_4 Emissions from Land Converted to Coastal Wetlands	NC	NC	NC	NC	NC	NC	NC
Settlements Remaining Settlements	**NC**	**NC**	**NC**	**0.1**	**0.1**	**+**	**+**
Changes in Organic Soil Carbon Stocks	NC	NC	NC	+	+	+	+
Changes in Urban Tree Carbon Stocks	NC	NC	NC	NC	NC	NC	NC
Changes in Yard Trimming and Food Scrap Carbon Stocks in Landfills	NC	NC	NC	NC	NC	NC	NC
N_2O Emissions from Settlement Soils[f]	NC	NC	NC	+	0.1	+	+
Land Converted to Settlements	**NC**	**NC**	**NC**	**0.1**	**(0.1)**	**(0.2)**	**+**
Changes in all Ecosystem Carbon Stocks[d]	NC	NC	NC	0.1	(0.1)	(0.2)	+
LULUCF Emissions[g]	**+**	**+**	**+**	**+**	**(0.1)**	**18.4**	
LULUCF Total Net Flux[h]	**+**	**(0.2)**	**0.3**	**27.2**	**21.1**	**45.3**	
LULUCF Sector Total[i]	**+**	**(0.2)**	**0.3**	**27.2**	**21.0**	**63.7**	
Percent Change	**0.0%**	**0.0%**	**0.0%**	**3.6%**	**2.8%**	**8.4%**	

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.

[a] Includes the net changes to carbon stocks stored in all forest ecosystem pools (including drained and undrained organic soils) and harvested wood products.

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

[c] Includes the net changes to carbon stocks stored in all forest ecosystem pools (excludes drained organic soils which are included in the flux from *Forest Land Remaining Forest Land* because it is not possible to separate the activity data at this time).

[d] 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.

[e] Includes carbon stock changes for land converted to vegetated coastal wetlands.

[f] Estimates include emissions from N fertilizer additions on both *Settlements Remaining Settlements* and *Land Converted to Settlements*.

[g] 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.

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

[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.