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Center for Biological Diversity/Sierra Club California Comments on Draft Staff Paper re AB 1110 Implementation

Additional submitted attachment is included below.

August 11, 2017

Via electronic filing:
https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=16-OIR-05

California Energy Commission
Docket Unit, MS-4
Re: Docket No. 16-OIR-05
1516 Ninth Street
Sacramento, CA 95814-5512

Re: AB 1110 Implementation Rulemaking (Docket No. 16-OIR-05):
Comments on Draft Staff Paper: Assembly Bill 1110 Implementation Proposal for Power Source Disclosure

To Whom It May Concern:

The Center for Biological Diversity and Sierra Club California appreciate the opportunity to submit the following comments on the Draft Staff Paper: Assembly Bill 1110 Implementation Proposal for Power Source Disclosure ("Staff Paper") docketed in the above-referenced proceeding on June 27, 2017.[1]

AB 1110 requires accurate, reliable, and easily understandable disclosure of "all" greenhouse gas emissions "associated" with electricity generation through the Power Source Disclosure ("PSD") program. In many respects, the proposals in the Staff Paper reflect these requirements by relying on actual greenhouse gas emissions data rather than on inaccurate reporting conventions derived from the renewable portfolio standard ("RPS") program, the cap and trade program, and other sources. Adherence to methods and data from the state's greenhouse gas monitoring and reporting ("MRR") program serves as a useful guide, and ensures consistency, in this respect.

There is, however, one major exception to this general approach: the Staff Paper proposes to exclude carbon dioxide ("CO_2") emissions from generation using biomass and other biologically

[1] Jordan Scavo, Renewable Energy Division, California Energy Commission, Draft Staff Paper: Assembly Bill 1110 Implementation Proposal for Power Source Disclosure (TN#219931).

based fuels[2] from the greenhouse gas intensity calculation required by AB 1110. As discussed in detail below and in prior comments filed by the Center for Biological Diversity,[3] this proposal is contrary to the plain text and purpose of AB 1110, scientifically unsupportable, inconsistent with the MRR, arbitrary, and unlawful. This legally and factually erroneous proposal must be rejected, and accurate accounting for biomass CO_2 emissions must be included, in forthcoming regulations.

I. AB 1110 Requires Accurate Accounting of All Emissions Associated with Electricity Production.

The plain language and intent of AB 1110 are clear: a power content label must disclose "accurate" and "reliable" information on all greenhouse gas emissions "associated" with "sources of energy . . . used to provide electric services."[4] This disclosure must compare the "greenhouse gas emissions intensity" of the "electricity portfolio" offered to customers by a particular "retail supplier" with the "greenhouse gas emissions intensity associated with all statewide retail electricity sales."[5]

AB 1110 charged the Energy Commission with adopting a methodology, in consultation with the Air Resources Board, "for the calculation of greenhouse gas emissions intensity for each purchase of electricity by a retail supplier to serve its retail customers."[6] However, the statute limits the Commission's discretion in carrying out this requirement by mandating a specific, straightforward methodology: "greenhouse gas emissions intensity" is defined as "the sum of all annual emissions of greenhouse gases associated with a generation source divided by the annual

[2] Unless otherwise specified, general references to "biomass" in these comments encompass not only solid biomass materials used as fuel, but also solid, liquid, and gaseous fuels derived from biomass materials, including but not limited to wood and wood chips, torrefied wood, pellets, biogas, biomass-derived syngas, and biomethane.
[3] Center for Biological Diversity, Comments Re: Docket No. 16-OIR-05: Pre-Rulemaking Updates to the Power Source Disclosure Regulations (AB 1110 Implementation) (March 15, 2017) ("Center Scoping Comments"). The Center Scoping Comments and all exhibits thereto are hereby incorporated by reference.
[4] Pub. Utilities Code § 398.1(b) ("The purpose of this article is to establish a program under which entities offering electric services in California disclose accurate, reliable, and simple to understand information on the sources of energy, and the associated emissions of greenhouse gases, that are used to provide electric services").
[5] Pub. Utilities Code § 398.4(a) ("Every retail supplier that makes an offering to sell electricity that is consumed in California shall disclose its electricity sources and the associated greenhouse gases emissions intensity for the previous calendar year"), (k)(1) ("Each retail supplier shall disclose both the greenhouse gas emissions intensity of any electricity portfolio offered to its retail customers and the Energy Commission's calculation of greenhouse gas emissions intensity associated with all statewide retail electricity sales, consistent with the requirements of this subdivision.").
[6] Pub. Utilities Code § 398.4(k)(2)(A).

production of electricity from the generation source."[7] Put another way, the greenhouse gas emissions intensity calculation consists of a simple fraction: "all annual emissions . . . associated with a generation source" must be in included in the numerator, while the denominator must reflect "the annual production of electricity" from the same source.

The Staff Paper reflects many of the statute's requirements in general terms. The paper recognizes that AB 1110 modifies the PSD program by "requiring retail suppliers to disclose the GHG emissions intensity (the rate of emissions per unit of electricity) associated with the electricity portfolios used to serve retail load."[8] The Staff Paper also articulates a number of "General Principles" derived from AB 1110. For example, the Staff Paper acknowledges that PSD is a "consumer transparency program" under which retail suppliers must "[p]resent information disclosed to customers on the Power Content Label in a manner that is accurate, reliable, consistent, and simple to understand," and that the Commission must "[r]ely on the most recent verified GHG emissions data in developing GHG emissions intensity factors." To this end, "staff proposes a method to construct a retail supplier's GHG emissions intensity factor largely based on data reported through and methods used by the Mandatory Greenhouse Gas Reporting Regulation."[9]

The purpose of AB 1110 is therefore plain on the face of its text: to provide California electricity consumers with accurate, reliable information on greenhouse gas emissions from energy generation, calculated using a simple formula that expressly includes "all" emissions "associated" with the production of electricity.

II. The Staff Paper's Proposal to Exclude Disclosure of CO_2 Emissions from Biomass Generation is Arbitrary and Unlawful.

In proposing that biomass CO_2 emissions be excluded from greenhouse gas intensity calculations and disclosure, the Staff Paper deviates sharply from the "methods" used in the MRR program and contravenes the mandatory requirements of AB 1110. This proposal must be withdrawn.

The Staff Paper acknowledges that unlike other renewables, biomass and biogas generation have associated GHG emissions that must be reported under MRR: "Although the terms are sometimes conflated, not all renewable resources are GHG-free. Under MRR, geothermal generators and generators that use biogenic fuels are required to report their GHG emissions."[10] Commission staff similarly acknowledged at a July 14, 2017 workshop that "[b]iomass, biomethane, and some geothermal generators emit GHGs," including CO_2 emissions that must be "tracked" under the MRR program.[11]

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[7] Pub. Utilities Code § 398.2(a).
[8] Staff Paper at 3.
[9] Staff Paper at 1; see *id.* at 4-5 (recognizing importance of MRR program).
[10] Staff Paper at 7.
[11] Transcript of the 07/14/2017 Workshop Updated to the Power Source Disclosure Regulations (TN#220318) ("7/14/17 Transcript") at 8:14-17.

The Staff Paper nonetheless proposes that retail suppliers should not be required to "report" or "disclose" CO_2 from combustion of "biogenic" fuels: "Staff proposes that retail suppliers should report and disclose fugitive GHG emissions from geothermal generators in their Power Content Labels, but not CO_2 emitted from electricity generators burning biogenic fuels. CH_4 and N_2O from biogenic fuels, however, would be included in a generator's emissions intensity."[12] The paper claims that "[t]his treatment would be consistent with electricity sector GHG accounting practices used by CARB's GHG Emission Inventory and IPCC [Intergovernmental Panel on Climate Change] guidance."[13]

Exclusion of biomass CO_2 emissions from "greenhouse gas emissions intensity" calculations conflicts with the plain text of AB 1110. The statute clearly requires that the "sum of *all* annual emissions of greenhouse gases associated with a generation source" be included in the intensity calculation.[14] The Staff Paper acknowledges that greenhouse gas emissions associated with energy production from "biogenic" fuels include CO_2, methane ("CH_4"), and nitrous oxide ("N_2O"). Yet the paper proposes to include only some (CH_4 and N_2O)—not "all"—of these emissions in the intensity calculation for sources using biomass fuels.[15] This proposal thus runs directly counter to the plain text of AB 1110.

The Staff Paper's proffered explanation for the proposal—that it is consistent with the treatment of biomass CO_2 in California's greenhouse gas inventory and IPCC guidance—is inaccurate and cannot justify a deviation from clear statutory requirements in any event. For example, the Staff Paper claims that "biogenic CO_2 is reported but not counted in CARB's GHG Emission Inventory."[16] This is incorrect. The MRR program, data from which are used to generate the state's inventory, specifically requires reporting of biomass greenhouse gas emissions.[17] Biogenic CO_2 also is "counted" in the California inventory itself; indeed, the latest inventory shows biomass electricity generation produced nearly 8 million tonnes of CO_2-equivalent greenhouse gases ("CO_2e") in 2015.[18] The national inventory produced by U.S. EPA similarly "counts" biomass CO_2, although it uses the IPCC convention of "counting" those emissions in

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[12] Staff Paper at 8.
[13] *Ibid.*; 7/14/17 Transcript at 8:18-9:1 (purporting to follow IPCC Guidance for GHG inventories by excluding biomass CO_2 emissions).
[14] Pub. Utilities Code § 398.2(a) (emphasis added).
[15] Staff Paper at 8.
[16] Staff Paper at 7.
[17] 17 Cal. Code Regs., §§ 95101(b)(4), 95103(a)(2), (j).
[18] California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category at 6-7 (updated June 6, 2017), *available at* https://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_ipcc_sum_2000-15.pdf (visited July 26, 2017) (attached as Ex. 1). Significantly, California's inventory currently includes no data on "Forested Lands and Wood Products," meaning that the state's inventory currently "counts" biogenic CO_2 in its own separate section rather than in sections addressing forestry, agriculture, or other land uses. *Id.* at 8 (describing "Forested Lands and Wood Products" section of inventory as "currently under development").

the Land Use, Land Use Change, and Forestry sector rather than in the Energy sector.[19] That said, the inventory still reports emissions from biomass combustion for energy production separately for informational purposes.[20] And the IPCC itself has made clear that its accounting conventions—which report bioenergy emissions in the Agriculture, Forestry, and Other Land Use sector rather than the Energy sector—should not be interpreted as suggesting that biomass is somehow "carbon neutral" or that biomass CO_2 emissions have no effect on the climate.[21]

Accordingly, under the California and U.S. inventories—both of which follow IPCC guidance—and the MRR program, biomass CO_2 emissions from energy production are reported in order to provide accurate and comprehensive information, even if those emissions are technically assigned to a different economic sector in the overall inventory. Nothing in either inventory, IPCC guidance, or the MRR program prohibits or otherwise counsels against disclosure of this information.

AB 1110 serves a similar informational purpose. By failing to disclose biomass emissions at all in the context of the PSD program, the Staff Paper's proposal would be inconsistent with the approaches taken in the MRR program and the state and federal inventories. And even if there were some inconsistency between AB 1110's approach and conventions used in preparing inventories, the specific terms of AB 1110 must control here; by specifically requiring that the "sum of all" greenhouse gas emissions "associated" with a generation source be included in calculations of that source's emissions intensity, the statute itself mandates disclosure of CO_2 emissions associated with biomass energy production, even if IPCC guidance or inventory conventions suggested otherwise (which, as shown above, they do not).

The Staff Paper's approach to biomass CO_2 is also inconsistent with its treatment of other emissions. For example, the Staff Paper proposes to require reporting and disclosure of fugitive emissions from geothermal energy production which, like biomass emissions, are reported under MRR but do not give rise to compliance obligations under the cap and trade program.[22] The Staff Paper also proposes that the emissions intensity of firmed-and-shaped products be calculated using the actual emissions profile of substitute generation rather than attributes of the generation that produced renewable energy credits (RECs); the paper deems this treatment necessary in order to maintain consistency with the MRR program, "bring additional transparency regarding the GHG emissions intensity associated with electricity portfolios," and

[19] See U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks 2000-2015 (EPA 430-P-17-001) at ES-7, 2-12 (April 2017) ("EPA GHG Inventory 2000-2015"), *available at* https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf (visited July 26, 2017) (excerpts attached as Ex. 2).
[20] See EPA GHG Inventory 2000-2015 at ES-6 (reporting total emissions from combustion of wood and other biologically derived fuels), 2-11 (reporting nearly 200 million tonnes of CO_2 emissions from "Biomass—Wood" used for "energy" in 2015).
[21] Intergovernmental Panel on Climate Change, Task Force on National Greenhouse Gas Inventories, Frequently Asked Questions, Q2-10, at http://www.ipcc-nggip.iges.or.jp/faq/faq.html (visited July 26, 2017) (attached as Ex. 3).
[22] Staff Paper at 8.

provide "a more accurate accounting" to consumers.[23] The Staff Paper proposes similar treatment for unbundled RECs.[24] The consistency with which the Staff Paper applies these principles in other contexts highlights the arbitrary nature of its approach to biomass CO_2.

III. The Commission's Regulations Can and Must Require Informational Disclosure of Biomass CO_2 Emissions.

Including biomass CO_2 emissions in greenhouse gas intensity calculations, consistent with the plain text and purpose of AB 1110, would be of great informational value to consumers and very easy to accomplish. The Staff Paper's proposed approach to unbundled RECs suggests a possible approach: "a retail supplier would report its unbundled RECs separately in its PSD filing and reflect the percentage of retail sales associated with unbundled RECs on the Power Content Label as a footnote."[25] Something similar could be done with biomass and biogas emissions intensity factors; emissions intensity based on actual generation could be reported, in accordance with the plain text of AB 1110, while any additional explanation of how biomass CO_2 is treated under IPCC guidelines, inventory conventions, or the cap and trade program could be provided in a footnote.[26]

Moreover, emissions factors for combustion of biomass and other biologically derived fuels are readily available. For facilities that report their emissions under MRR, facility-specific

[23] Staff Paper at 12-13; see also 7/14/17 Transcript at 13:20-14:6 (declining to apply cap-and-trade RPS adjustment to firmed and shaped products because PSD is not a "compliance program that imposes direct financial costs on GHG emissions").
[24] Staff Paper at 14. In this context, the undersigned appreciate and support the comments addressing unbundled RECs, firmed-and-shaped products, and the general purposes of the AB 1110 program offered by Matthew Freedman of The Utility Reform Network at the July 14, 2017 workshop. See 7/14/17 Transcript at 52:3-55:21.
[25] Staff Paper at 14.
[26] Such a footnote is not strictly necessary, but may help address any misplaced concern that including all emissions associated with bioenergy generation in the greenhouse gas emissions intensity calculation might represent "double counting" in relation to cap and trade, inventory conventions, or IPCC guidelines. To be clear, including biomass CO_2 emissions in PSD disclosures poses no risk of "double counting" with respect to AB 1110 or the PSD program itself. The statute directs the Commission to "[e]nsure that there is no double-counting of the greenhouse gas emissions or emissions attributes associated with any unit of electricity production reported by a retail supplier for any specific generating facility or unspecified source located within the Western Electricity Coordinating Council *when calculating greenhouse gas emissions intensity*." Pub. Utilities Code § 398.4(k)(2)(E) (emphasis added). In other words, the Commission simply must ensure that the same emissions are not included twice in the "sum of all" emissions required to be included in the intensity calculation. If the Commission wished, however, the power content label presumably could include a footnote stating that biomass CO_2 emissions are accounted separately from fossil emissions in the Energy section of state and federal greenhouse gas inventories and that such emissions do not give rise to a compliance obligation under the cap and trade system.

emissions factors should be used in intensity calculations. For facilities that do not report their emissions under MRR (such as facilities generating less than 1 MW or emitting less than 10,000 tons CO_2e annually), the Commission should develop a default factor using EPA emissions factors (depending on whether facilities use solid fuels or biogas). The Staff Paper proposes to use EIA emissions factors, which do not include factors for biomass.[27] The EPA emissions factors from which EIA factors are drawn, however, include factors for solid biomass and biomass gases.[28]

For all of the foregoing reasons, therefore, the Commission can and must include biomass CO_2 emissions in the greenhouse gas intensity calculation under AB 1110. Thank you for the opportunity to submit these comments. We look forward to working with commissioners and staff as the regulatory process moves forward.

Sincerely,

Kevin P. Bundy
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Center for Biological Diversity

Kathryn Phillips
Director
Sierra Club California

Exhibits:

1	California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category (updated June 6, 2017).
2	U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks 2000-2015 (EPA 430-P-17-001) (April 2017) (excerpts).
3	Intergovernmental Panel on Climate Change, Task Force on National Greenhouse Gas Inventories, Frequently Asked Questions, Q2-10.
4	U.S. EPA, Emission Factors for Greenhouse Gas Inventories (April 4, 2014).

[27] Staff Paper at 9 n.10.
[28] U.S. EPA, Emission Factors for Greenhouse Gas Inventories (April 4, 2014), *available at* https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf (visited July 25, 2017) (attached as Ex. 4).

EXHIBIT 1

California Environmental Protection Agency

Air Resources Board

California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category

million tonnes of CO2 equivalent - (based upon IPCC Fourth Assessment Report's 100-yr Global Warming Potentials)

Inventory Emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1 - Energy	**408.9**	**423.8**	**420.6**	**419.6**	**427.7**	**418.9**	**414.3**	**419.0**	**415.5**	**388.4**	**379.1**	**370.6**	**375.0**	**372.7**	**367.7**	**365.6**
1A - Fuel Combustion Activities	***401.83***	***416.69***	***413.15***	***412.36***	***420.32***	***411.14***	***406.32***	***411.26***	***407.78***	***380.47***	***371.19***	***362.43***	***367.26***	***364.58***	***359.34***	***356.88***
1A1 - Energy Industries	**159.12**	**175.95**	**161.56**	**167.81**	**172.76**	**163.91**	**157.64**	**165.74**	**171.53**	**154.35**	**144.85**	**137.10**	**144.24**	**141.87**	**139.95**	**132.93**
1A1a - Main Activity Electricity and Heat Production	116.37	132.29	119.12	122.23	127.49	119.41	115.87	124.33	129.70	113.42	102.69	98.70	105.80	100.40	97.51	92.05
1A1ai - Electricity Generation	*84.804*	*103.488*	*86.517*	*92.858*	*98.058*	*91.186*	*88.839*	*98.216*	*104.626*	*84.201*	*75.849*	*72.105*	*81.077*	*75.019*	*72.533*	*69.650*
1A1aii - Combined Heat and Power Generation (CHP)	*31.565*	*28.804*	*32.600*	*29.375*	*29.427*	*28.227*	*27.034*	*26.115*	*25.072*	*29.215*	*26.842*	*26.597*	*24.727*	*25.383*	*24.979*	*22.399*
1A1b - Petroleum Refining	24.67	25.23	25.33	26.03	25.31	25.93	25.57	25.06	24.28	24.59	26.54	22.85	22.80	23.85	23.95	22.35
1A1c - Manufacture of Solid Fuels and Other Energy Industries	18.09	18.43	17.11	19.55	19.96	18.56	16.19	16.35	17.56	16.35	15.61	15.54	15.64	17.62	18.48	18.53
1A1cii - Other Energy Industries	*18.085*	*18.429*	*17.109*	*19.545*	*19.964*	*18.563*	*16.192*	*16.353*	*17.557*	*16.350*	*15.610*	*15.544*	*15.636*	*17.621*	*18.485*	*18.529*
1A2 - Manufacturing Industries and Construction	**22.75**	**21.58**	**22.90**	**19.28**	**19.52**	**18.63**	**18.71**	**17.01**	**18.11**	**16.62**	**18.72**	**19.54**	**19.78**	**20.29**	**20.22**	**19.98**
1A2c - Chemicals	4.55	4.08	3.97	2.60	3.22	3.81	3.79	3.13	3.91	3.82	5.36	6.32	5.71	5.67	6.47	6.02
1A2d - Pulp, Paper and Print	1.05	0.94	1.01	0.92	0.94	0.62	0.64	0.55	0.46	0.40	0.40	0.44	0.44	0.43	0.41	0.44
1A2e - Food Processing, Beverages and Tobacco	3.89	3.51	3.80	3.12	3.16	3.02	3.31	3.32	3.18	3.12	3.08	3.16	3.26	3.27	3.30	3.32
1A2f - Non-Metallic Minerals	5.42	5.28	5.47	5.29	5.27	5.32	5.32	4.78	4.34	2.94	2.90	2.86	3.07	3.05	3.12	3.20
1A2g - Transport Equipment	0.46	0.48	0.52	0.31	0.27	0.27	0.26	0.28	0.29	0.25	0.25	0.24	0.24	0.28	0.27	0.27
1A2h - Machinery	1.75	1.27	1.33	0.98	1.01	1.02	1.04	0.99	0.93	0.82	0.80	0.82	0.81	0.79	0.77	0.76
1A2i - Mining (excluding fuels) and Quarrying	0.86	0.31	0.31	0.34	0.36	0.34	0.11	0.16	0.19	0.14	0.15	0.15	0.17	0.16	0.15	0.15
1A2j - Wood and Wood Products	0.40	0.31	0.19	0.16	0.11	0.11	0.11	0.08	0.07	0.05	0.05	0.04	0.03	0.03	0.04	0.04
1A2k - Construction	0.41	0.60	0.62	0.62	0.75	0.72	0.60	0.48	0.42	0.41	0.48	0.47	0.64	1.26	0.71	0.33
1A2l - Textile and Leather	0.56	0.54	0.59	0.45	0.44	0.43	0.39	0.35	0.31	0.23	0.24	0.23	0.22	0.22	0.21	0.20
1A2m - Non-specified Industry.	2.60	3.46	4.17	3.75	3.27	2.36	2.70	2.36	3.49	4.08	4.55	4.32	4.67	4.60	4.24	4.79
1A3 - Transport	**175.29**	**175.57**	**182.58**	**180.03**	**181.67**	**183.47**	**183.47**	**183.40**	**172.24**	**165.52**	**162.07**	**158.79**	**158.62**	**157.27**	**159.13**	**163.64**
1A3a - Civil Aviation	4.15	4.07	4.12	4.25	4.49	4.49	4.56	4.97	4.50	4.03	3.84	3.71	3.75	3.91	3.89	4.20
1A3aii - Domestic Aviation	*3.885*	*3.829*	*3.848*	*3.983*	*4.254*	*4.281*	*4.360*	*4.755*	*4.318*	*3.883*	*3.717*	*3.613*	*3.601*	*3.774*	*3.718*	*4.016*
1A3b - Road Transportation	162.35	162.70	168.72	165.43	166.56	167.36	166.91	167.00	157.39	152.85	149.03	145.92	145.67	143.86	144.98	149.42
1A3bi - Cars	*66.046*	*64.501*	*65.669*	*61.366*	*59.783*	*58.245*	*57.425*	*56.907*	*53.771*	*53.633*	*52.271*	*51.055*	*51.809*	*51.893*	*52.776*	*55.741*
1A3bii - Light-duty Trucks	*59.325*	*61.305*	*64.905*	*65.968*	*66.956*	*68.040*	*68.052*	*67.845*	*64.517*	*63.155*	*61.190*	*59.661*	*59.351*	*58.207*	*57.947*	*59.896*
1A3biii - Heavy-duty Trucks and Buses	*36.626*	*36.447*	*37.650*	*37.552*	*39.243*	*40.165*	*40.448*	*41.172*	*37.968*	*34.880*	*34.366*	*33.958*	*33.267*	*32.635*	*32.905*	*32.407*
1A3biv - Motorcycles	*0.230*	*0.298*	*0.340*	*0.357*	*0.368*	*0.402*	*0.445*	*0.473*	*0.493*	*0.487*	*0.463*	*0.450*	*0.451*	*0.445*	*0.449*	*0.473*
1A3c - Railways	1.88	1.89	2.50	2.86	2.91	3.34	3.53	3.17	2.38	1.95	2.31	2.64	2.47	2.40	2.75	2.42
1A3d - Water-borne Navigation	3.50	3.32	3.63	3.79	3.80	4.05	4.09	4.26	4.01	3.64	3.71	3.56	3.60	3.86	3.95	3.89
1A3di - International Water-borne Navigation (International Bunkers)	*1.128*	*1.184*	*1.243*	*1.304*	*1.369*	*1.436*	*1.487*	*1.573*	*1.458*	*1.216*	*1.367*	*1.329*	*1.290*	*1.478*	*1.532*	*1.519*
1A3dii - Domestic Water-borne Navigation	*2.376*	*2.138*	*2.390*	*2.490*	*2.432*	*2.612*	*2.607*	*2.684*	*2.551*	*2.422*	*2.344*	*2.233*	*2.314*	*2.385*	*2.418*	*2.368*
1A3e - Other Transportation	2.63	2.79	2.77	2.84	3.03	3.22	3.32	3.18	2.82	2.25	2.03	2.13	2.23	2.33	2.43	2.53
1A3eii - Off-road	*2.631*	*2.790*	*2.768*	*2.843*	*3.029*	*3.217*	*3.315*	*3.176*	*2.819*	*2.246*	*2.033*	*2.133*	*2.234*	*2.334*	*2.434*	*2.533*

Inventory Emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1A4 - Other Sectors	**44.67**	**43.60**	**46.11**	**45.23**	**46.37**	**45.14**	**46.50**	**45.11**	**45.90**	**43.97**	**45.55**	**47.01**	**44.62**	**45.14**	**40.05**	**40.33**
1A4a - Commercial/Institutional	11.47	11.31	13.11	12.84	12.70	12.55	12.83	12.82	12.99	12.89	13.58	13.71	13.41	13.30	12.51	12.77
1A4b - Residential	29.38	28.47	28.62	28.14	29.17	27.98	28.36	28.50	28.82	28.47	29.19	29.64	27.34	28.14	22.87	23.17
1A4c - Agriculture/Forestry/Fishing/Fish Farms	3.81	3.82	4.38	4.25	4.50	4.60	5.30	3.78	4.09	2.61	2.77	3.65	3.88	3.71	4.66	4.39
1B - Fugitive Emissions from Fuels	***7.05***	***7.14***	***7.49***	***7.27***	***7.36***	***7.73***	***7.93***	***7.74***	***7.76***	***7.96***	***7.87***	***8.18***	***7.70***	***8.16***	***8.39***	***8.68***
1B1 - Solid Fuels	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.03**	**0.03**	**0.03**	**0.03**	**0.02**	**0.02**	**0.02**	**0.02**	**0.01**	**0.02**	**0.01**
1B2 - Oil and Natural Gas	**5.78**	**5.88**	**6.24**	**6.03**	**6.10**	**6.46**	**6.68**	**6.48**	**6.54**	**6.52**	**6.68**	**6.88**	**6.83**	**7.21**	**7.44**	**7.51**
1B2a - Oil	0.48	0.46	0.47	0.46	0.44	0.46	0.48	0.47	0.46	0.45	0.49	0.52	0.47	0.61	0.64	0.54
1B2ai - Venting	*0.067*	*0.069*	*0.069*	*0.071*	*0.069*	*0.071*	*0.073*	*0.072*	*0.071*	*0.066*	*0.053*	*0.072*	*0.061*	*0.160*	*0.214*	*0.151*
1B2aii - Flaring	*0.057*	*0.058*	*0.058*	*0.059*	*0.058*	*0.060*	*0.061*	*0.061*	*0.060*	*0.055*	*0.055*	*0.128*	*0.106*	*0.104*	*0.093*	*0.085*
1B2aiii - All Other	*0.358*	*0.331*	*0.338*	*0.330*	*0.315*	*0.334*	*0.341*	*0.338*	*0.330*	*0.324*	*0.377*	*0.322*	*0.305*	*0.343*	*0.337*	*0.303*
1B2b - Natural Gas [1]	3.64	3.70	4.03	3.78	3.85	3.89	4.03	4.00	4.08	4.12	4.08	4.07	3.98	3.98	4.00	4.06
1B3 - Geothermal Energy Production	**1.13**	**1.11**	**1.11**	**1.10**	**1.12**	**1.12**	**1.10**	**1.11**	**1.09**	**1.31**	**1.10**	**1.22**	**0.83**	**0.93**	**0.92**	**1.15**
1B4 - Pollution control devices	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.10**	**0.10**	**0.06**	**0.05**	**0.02**	**0.00**	**0.00**	**0.00**
2 - Industrial Processes and Product Use	**19.6**	**19.1**	**19.9**	**20.4**	**21.3**	**22.0**	**23.0**	**23.7**	**23.9**	**22.2**	**23.5**	**28.4**	**29.6**	**29.3**	**30.8**	**32.5**
2A - Mineral Industry	***5.60***	***5.35***	***5.88***	***5.93***	***6.11***	***6.04***	***5.88***	***5.71***	***5.33***	***3.63***	***3.49***	***4.11***	***4.69***	***4.97***	***5.32***	***5.23***
2A1 - Cement Production	**5.52**	**5.28**	**5.82**	**5.87**	**6.03**	**5.96**	**5.81**	**5.66**	**5.28**	**3.60**	**3.46**	**4.08**	**4.65**	**4.93**	**5.27**	**5.17**
2A2 - Lime Production	**0.07**	**0.07**	**0.06**	**0.06**	**0.08**	**0.07**	**0.07**	**0.05**	**0.04**	**0.03**	**0.03**	**0.04**	**0.04**	**0.04**	**0.05**	**0.06**
2B - Chemical Industry	***0.06***	***0.05***	***0.05***	***0.05***	***0.05***	***0.05***	***0.05***	***0.06***	***0.05***	***0.04***	***0.05***	***0.03***	***0.05***	***0.05***	***0.01***	***0.03***
2B2 - Nitric Acid Production	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.06**	**0.05**	**0.04**	**0.05**	**0.03**	**0.05**	**0.05**	**0.01**	**0.03**
2C - Metal Industry	***0.07***	***0.07***	***0.07***	***0.07***	***0.07***	***0.07***	***0.07***	***0.07***	***0.07***	***0.06***	***0.07***	***0.07***	***0.06***	***0.07***	***0.06***	***0.05***
2C5 - Lead Production	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.06**	**0.07**	**0.07**	**0.06**	**0.07**	**0.06**	**0.05**
2D - Non-Energy Products from Fuels and Solvent Use	***2.46***	***2.26***	***2.20***	***2.07***	***2.06***	***2.04***	***2.00***	***2.05***	***1.92***	***1.74***	***1.91***	***1.81***	***1.68***	***1.70***	***1.83***	***1.90***
2D1 - Lubricant Use	**2.09**	**1.92**	**1.89**	**1.75**	**1.77**	**1.77**	**1.72**	**1.78**	**1.65**	**1.48**	**1.65**	**1.56**	**1.44**	**1.52**	**1.59**	**1.73**
2D3 - Solvent Use	**0.37**	**0.35**	**0.30**	**0.31**	**0.28**	**0.28**	**0.28**	**0.28**	**0.27**	**0.26**	**0.27**	**0.25**	**0.24**	**0.18**	**0.24**	**0.17**
2E - Electronics Industry	***0.52***	***0.35***	***0.35***	***0.35***	***0.35***	***0.30***	***0.36***	***0.35***	***0.23***	***0.20***	***0.20***	***0.28***	***0.26***	***0.26***	***0.26***	***0.26***
2F - Product Uses as Substitutes for Ozone Depleting Substances	***6.10***	***6.23***	***6.52***	***7.20***	***7.95***	***8.75***	***9.64***	***10.43***	***11.27***	***11.96***	***13.20***	***14.21***	***15.25***	***16.38***	***17.42***	***18.37***
2G - Other Product Manufacture and Use	***1.52***	***1.42***	***1.45***	***1.38***	***1.39***	***1.37***	***1.39***	***1.39***	***1.38***	***1.28***	***1.20***	***1.16***	***1.12***	***1.14***	***1.17***	***1.39***
2G1 - Electrical Equipment	**0.51**	**0.49**	**0.44**	**0.42**	**0.40**	**0.37**	**0.33**	**0.29**	**0.30**	**0.27**	**0.24**	**0.25**	**0.24**	**0.18**	**0.14**	**0.42**
2G1b - Use of Electrical Equipment	0.51	0.49	0.44	0.42	0.40	0.37	0.33	0.29	0.30	0.27	0.24	0.25	0.24	0.18	0.14	0.42
2G4 - CO2, Limestone or Soda Ash consumption	**1.01**	**0.93**	**1.00**	**0.96**	**0.99**	**1.00**	**1.06**	**1.10**	**1.08**	**1.01**	**0.96**	**0.91**	**0.88**	**0.95**	**1.03**	**0.97**

California Environmental Protection Agency

Air Resources Board

California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category

million tonnes of CO_2 equivalent - (based upon IPCC Fourth Assessment Report's 100-yr Global Warming Potentials)

Inventory Emissions	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
2H - Other	***3.31***	***3.35***	***3.39***	***3.33***	***3.31***	***3.34***	***3.58***	***3.67***	***3.67***	***3.27***	***3.36***	***6.68***	***6.54***	***4.69***	***4.73***	***5.26***
2H3 - Hydrogen Production	**3.31**	**3.35**	**3.39**	**3.33**	**3.31**	**3.34**	**3.58**	**3.67**	**3.67**	**3.27**	**3.36**	**6.68**	**6.54**	**4.69**	**4.73**	**5.26**
3 - Agriculture, Forestry and Other Land Use	**29.4**	**29.4**	**31.0**	**31.4**	**30.7**	**31.2**	**31.7**	**33.6**	**33.3**	**32.6**	**33.2**	**33.0**	**33.9**	**32.6**	**32.8**	**31.7**
3A - Livestock	***19.62***	***19.89***	***21.17***	***21.61***	***20.81***	***21.46***	***21.81***	***24.13***	***24.13***	***23.41***	***24.00***	***23.84***	***24.47***	***23.49***	***23.81***	***23.25***
3A1 - Enteric Fermentation	**10.36**	**10.25**	**10.91**	**11.00**	**10.77**	**11.08**	**11.13**	**12.31**	**12.04**	**11.65**	**12.13**	**11.98**	**12.10**	**11.78**	**11.85**	**11.54**
3A1a - Cattle	10.01	9.89	10.54	10.60	10.34	10.60	10.66	11.84	11.57	11.17	11.65	11.49	11.61	11.29	11.36	11.05
3A1ai - Dairy Cows	*6.743*	*6.665*	*7.331*	*7.417*	*7.217*	*7.392*	*7.547*	*8.461*	*8.360*	*7.995*	*8.496*	*8.436*	*8.488*	*8.225*	*8.240*	*8.081*
3A1aii - Other Cattle	*3.264*	*3.221*	*3.210*	*3.185*	*3.125*	*3.212*	*3.110*	*3.376*	*3.210*	*3.173*	*3.154*	*3.054*	*3.121*	*3.070*	*3.124*	*2.971*
3A1c - Sheep	0.16	0.16	0.15	0.15	0.14	0.14	0.13	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12
3A1d - Goats	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3A1f - Horses	0.18	0.19	0.20	0.24	0.27	0.31	0.32	0.32	0.32	0.33	0.34	0.35	0.35	0.35	0.35	0.35
3A1h - Swine	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3A2 - Manure Management	**9.26**	**9.64**	**10.25**	**10.60**	**10.04**	**10.39**	**10.68**	**11.82**	**12.09**	**11.75**	**11.86**	**11.86**	**12.38**	**11.71**	**11.96**	**11.71**
3A2a - Cattle	8.88	9.28	9.88	10.24	9.69	10.02	10.33	11.46	11.77	11.41	11.53	11.52	12.04	11.40	11.67	11.42
3A2ai - Dairy Cows	*8.541*	*8.931*	*9.504*	*9.837*	*9.308*	*9.625*	*9.907*	*11.033*	*11.354*	*11.016*	*11.142*	*11.140*	*11.644*	*11.003*	*11.244*	*10.994*
3A2aii - Other Cattle	*0.342*	*0.345*	*0.372*	*0.399*	*0.381*	*0.398*	*0.418*	*0.424*	*0.414*	*0.396*	*0.385*	*0.382*	*0.396*	*0.395*	*0.426*	*0.426*
3A2c - Sheep	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03
3A2d - Goats	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3A2f - Horses	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09
3A2h - Swine	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.04	0.05	0.04	0.05	0.05	0.04	0.05	0.04
3A2i - Poultry	0.21	0.21	0.20	0.19	0.17	0.17	0.17	0.18	0.17	0.17	0.17	0.17	0.17	0.14	0.12	0.13
3C - Aggregate Sources and Non-CO2 Emissions Sources on Land	***9.76***	***9.49***	***9.88***	***9.82***	***9.84***	***9.77***	***9.91***	***9.44***	***9.18***	***9.16***	***9.23***	***9.16***	***9.45***	***9.13***	***8.96***	***8.42***
3C1 - Emissions from Biomass Burning	**0.08**	**0.06**	**0.06**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**
3C1b - Biomass Burning in Croplands	0.08	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
3C2 - Liming	**0.27**	**0.16**	**0.23**	**0.24**	**0.24**	**0.30**	**0.48**	**0.26**	**0.17**	**0.17**	**0.18**	**0.17**	**0.23**	**0.22**	**0.21**	**0.19**
3C4 - Direct N2O Emissions from Managed Soils	**6.42**	**6.45**	**6.59**	**6.57**	**6.44**	**6.42**	**6.39**	**6.15**	**6.01**	**5.92**	**5.99**	**5.85**	**6.08**	**5.78**	**5.91**	**5.49**
3C5 - Indirect N2O Emissions from Managed Soils	**1.81**	**1.79**	**1.83**	**1.85**	**1.82**	**1.84**	**1.84**	**1.81**	**1.80**	**1.80**	**1.79**	**1.80**	**1.85**	**1.83**	**1.81**	**1.75**
3C7 - Rice Cultivations	**1.19**	**1.02**	**1.15**	**1.10**	**1.28**	**1.14**	**1.13**	**1.15**	**1.12**	**1.20**	**1.20**	**1.26**	**1.22**	**1.22**	**0.96**	**0.91**
4 - Waste	**9.3**	**9.4**	**9.4**	**9.5**	**9.5**	**9.7**	**9.8**	**9.9**	**10.0**	**10.2**	**10.3**	**10.4**	**10.4**	**10.5**	**10.5**	**10.6**
4A - Solid Waste Disposal	***7.22***	***7.36***	***7.31***	***7.43***	***7.42***	***7.59***	***7.65***	***7.71***	***7.88***	***8.02***	***8.11***	***8.19***	***8.20***	***8.22***	***8.28***	***8.40***
4A1 - Managed Waste Disposal Sites	**7.22**	**7.36**	**7.31**	**7.43**	**7.42**	**7.59**	**7.65**	**7.71**	**7.88**	**8.02**	**8.11**	**8.19**	**8.20**	**8.22**	**8.28**	**8.40**
4B - Biological Treatment of Solid Waste	***0.13***	***0.15***	***0.16***	***0.17***	***0.18***	***0.20***	***0.21***	***0.22***	***0.24***	***0.25***	***0.26***	***0.27***	***0.29***	***0.30***	***0.31***	***0.33***

California Environmental Protection Agency
Air Resources Board

California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category

million tonnes of CO2 equivalent - (based upon IPCC Fourth Assessment Report's 100-yr Global Warming Potentials)

Inventory Emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
4D - Wastewater Treatment and Discharge	***1.93***	***1.90***	***1.93***	***1.91***	***1.91***	***1.90***	***1.91***	***1.92***	***1.90***	***1.88***	***1.93***	***1.96***	***1.96***	***1.95***	***1.95***	***1.90***
4D1 - Domestic Wastewater Treatment and Discharge	**1.60**	**1.59**	**1.59**	**1.59**	**1.59**	**1.58**	**1.58**	**1.59**	**1.58**	**1.57**	**1.62**	**1.64**	**1.64**	**1.64**	**1.63**	**1.63**
4D2 - Industrial Wastewater Treatment and Discharge	**0.33**	**0.31**	**0.34**	**0.32**	**0.32**	**0.32**	**0.33**	**0.34**	**0.32**	**0.31**	**0.31**	**0.32**	**0.32**	**0.31**	**0.31**	**0.27**

Summary for Included Emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Included Inventory Emissions	**467.19**	**481.69**	**480.98**	**480.94**	**489.13**	**481.75**	**478.70**	**486.16**	**482.78**	**453.34**	**446.06**	**442.38**	**448.97**	**445.08**	**441.85**	**440.36**

[1] The exceptional Aliso Canyon natural gas leak event released 1.96 $MMTCO_2e$ of unanticipated emissions in calendar year 2015 and an additional 0.52 $MMTCO_2e$ in 2016. These emissions will be mitigated in the future according to legal settlement and are presented alongside but tracked separately from routine inventory emissions.

California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category

million tonnes of CO2 equivalent - (based upon IPCC Fourth Assessment Report's 100-yr Global Warming Potentials)

Excluded Emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1 - Energy	**55.3**	**48.9**	**53.6**	**48.0**	**51.8**	**54.7**	**56.9**	**59.6**	**55.9**	**55.4**	**57.0**	**54.8**	**53.9**	**55.0**	**57.7**	**60.2**
1A - Fuel Combustion Activities	***54.74***	***48.37***	***53.09***	***47.41***	***51.23***	***54.08***	***56.29***	***58.94***	***55.30***	***54.74***	***56.40***	***54.18***	***53.31***	***54.40***	***57.08***	***59.56***
1A3 - Transport	**50.93**	**44.01**	**48.96**	**43.25**	**47.35**	**50.67**	**53.18**	**56.01**	**52.53**	**52.04**	**53.30**	**51.50**	**50.01**	**51.51**	**53.53**	**56.57**
1A3a - Civil Aviation	35.18	32.51	35.19	33.80	36.18	35.84	36.79	38.44	34.87	34.20	33.50	34.00	32.70	35.01	37.41	40.20
1A3ai - International Aviation (International Bunkers)	*16.794*	*15.171*	*15.722*	*14.555*	*15.779*	*16.187*	*16.830*	*17.546*	*16.619*	*16.468*	*16.203*	*17.049*	*16.445*	*17.996*	*19.725*	*21.839*
1A3aii - Domestic Aviation	*18.389*	*17.334*	*19.467*	*19.245*	*20.396*	*19.650*	*19.958*	*20.899*	*18.250*	*17.733*	*17.297*	*16.948*	*16.253*	*17.016*	*17.685*	*18.365*
1A3d - Water-borne Navigation	15.75	11.51	13.77	9.45	11.18	14.83	16.39	17.57	17.66	17.84	19.79	17.51	17.32	16.50	16.12	16.37
1A3di - International Water-borne Navigation (International Bunkers)	*15.747*	*11.506*	*13.772*	*9.454*	*11.176*	*14.835*	*16.389*	*17.569*	*17.660*	*17.835*	*19.795*	*17.506*	*17.317*	*16.498*	*16.118*	*16.367*
1A5 - Non-Specified	**3.81**	**4.36**	**4.13**	**4.16**	**3.88**	**3.41**	**3.11**	**2.93**	**2.77**	**2.71**	**3.10**	**2.68**	**3.30**	**2.89**	**3.55**	**2.99**
1A5b - Mobile	3.74	4.07	3.64	3.66	3.34	3.31	3.00	2.81	2.68	2.56	2.58	2.31	2.87	2.38	2.38	2.38
1A5bi - Mobile (Aviation Component)	*3.736*	*4.069*	*3.640*	*3.661*	*3.338*	*3.313*	*3.004*	*2.807*	*2.682*	*2.562*	*2.584*	*2.308*	*2.874*	*2.379*	*2.379*	*2.379*
1B - Fugitive Emissions from Fuels	***0.55***	***0.54***	***0.55***	***0.55***	***0.56***	***0.57***	***0.59***	***0.62***	***0.62***	***0.61***	***0.60***	***0.60***	***0.60***	***0.57***	***0.59***	***0.59***
1B2 - Oil and Natural Gas	**0.55**	**0.54**	**0.55**	**0.55**	**0.56**	**0.57**	**0.59**	**0.62**	**0.62**	**0.61**	**0.60**	**0.60**	**0.60**	**0.57**	**0.59**	**0.59**

Summary for Excluded Emissions	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
International and Interstate Emissions	**55.3**	**48.9**	**53.6**	**48.0**	**51.8**	**54.7**	**56.9**	**59.6**	**55.9**	**55.4**	**57.0**	**54.8**	**53.9**	**55.0**	**57.7**	**60.2**

California Environmental Protection Agency
Air Resources Board

California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category

million tonnes of CO2 equivalent - (based upon IPCC Fourth Assessment Report's 100-yr Global Warming Potentials)

CO2 from biogenic materials	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1 - Energy	**16.6**	**16.8**	**15.2**	**18.2**	**19.8**	**19.4**	**19.1**	**19.0**	**19.2**	**21.1**	**23.3**	**24.7**	**24.6**	**30.0**	**29.7**	**28.1**
1A - Fuel Combustion Activities	***16.56***	***16.85***	***15.23***	***18.16***	***19.83***	***19.36***	***19.10***	***18.98***	***19.21***	***21.07***	***23.30***	***24.69***	***24.59***	***29.97***	***29.73***	***28.15***
1A1 - Energy Industries	**8.39**	**8.21**	**8.02**	**8.22**	**8.09**	**8.50**	**8.65**	**8.31**	**8.30**	**9.45**	**9.17**	**9.63**	**10.32**	**12.00**	**11.51**	**9.99**
1A1a - Main Activity Electricity and Heat Production	8.39	8.21	8.02	8.22	8.09	8.50	8.65	8.31	8.30	9.45	9.17	9.63	10.32	12.00	11.51	9.99
1A1ai - Electricity Generation	*5.249*	*4.790*	*5.687*	*5.638*	*5.414*	*5.530*	*5.670*	*5.343*	*5.513*	*7.180*	*7.143*	*6.973*	*7.669*	*9.164*	*8.951*	*7.748*
1A1aii - Combined Heat and Power Generation (CHP)	*3.137*	*3.419*	*2.338*	*2.581*	*2.679*	*2.966*	*2.983*	*2.968*	*2.783*	*2.266*	*2.023*	*2.654*	*2.655*	*2.834*	*2.555*	*2.237*
1A1b - Petroleum Refining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2 - Manufacturing Industries and Construction	**3.78**	**4.26**	**2.64**	**2.60**	**2.65**	**2.91**	**2.66**	**2.71**	**2.42**	**2.24**	**2.35**	**2.54**	**2.56**	**2.48**	**2.22**	**2.15**
1A2f - Non-Metallic Minerals	0.06	0.06	0.07	0.07	0.07	0.07	0.05	0.05	0.06	0.07	0.10	0.09	0.14	0.19	0.23	0.15
1A2k - Construction	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.03	0.04	0.08	0.05	0.02
1A2m - Non-specified Industry.	3.72	4.20	2.58	2.52	2.56	2.82	2.59	2.64	2.35	2.16	2.22	2.42	2.37	2.21	1.94	1.98
1A3 - Transport	**0.34**	**0.46**	**0.57**	**3.14**	**4.79**	**5.11**	**5.24**	**5.18**	**5.41**	**5.38**	**8.23**	**8.88**	**8.32**	**10.95**	**11.45**	**11.50**
1A3a - Civil Aviation	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1A3b - Road Transportation	0.34	0.46	0.57	3.12	4.77	5.08	5.21	5.15	5.38	5.35	8.19	8.84	8.28	10.91	11.40	11.45
1A3bi - Cars	*0.156*	*0.206*	*0.247*	*1.385*	*2.071*	*2.158*	*2.128*	*2.106*	*2.219*	*2.254*	*3.484*	*3.726*	*3.488*	*4.031*	*4.409*	*4.057*
1A3bii - Light-duty Trucks	*0.140*	*0.195*	*0.243*	*1.488*	*2.320*	*2.521*	*2.521*	*2.509*	*2.660*	*2.653*	*4.076*	*4.352*	*3.992*	*4.507*	*4.828*	*4.341*
1A3biii - Heavy-duty Trucks and Buses	*0.042*	*0.054*	*0.075*	*0.241*	*0.365*	*0.387*	*0.551*	*0.521*	*0.482*	*0.421*	*0.598*	*0.737*	*0.769*	*2.338*	*2.125*	*3.020*
1A3biv - Motorcycles	*0.001*	*0.001*	*0.001*	*0.007*	*0.012*	*0.014*	*0.015*	*0.016*	*0.019*	*0.019*	*0.028*	*0.030*	*0.028*	*0.031*	*0.034*	*0.031*
1A3d - Water-borne Navigation	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.03	0.04	0.04	0.04	0.03
1A3dii - Domestic Water-borne Navigation	*0.002*	*0.001*	*0.002*	*0.015*	*0.019*	*0.025*	*0.023*	*0.024*	*0.024*	*0.026*	*0.037*	*0.032*	*0.036*	*0.037*	*0.039*	*0.034*
1A4 - Other Sectors	**4.05**	**3.92**	**3.99**	**4.20**	**4.28**	**2.84**	**2.54**	**2.78**	**3.08**	**4.00**	**3.56**	**3.63**	**3.38**	**4.54**	**4.55**	**4.52**
1A4a - Commercial/Institutional	0.58	0.59	0.60	0.63	0.61	0.39	0.36	0.39	0.41	0.50	0.49	0.47	0.42	0.48	0.48	0.48
1A4b - Residential	3.47	3.33	3.38	3.56	3.65	2.43	2.15	2.38	2.66	3.50	3.05	3.12	2.91	4.02	4.02	4.02
1A4c - Agriculture/Forestry/Fishing/Fish Farms	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.04	0.05	0.03	0.04	0.01
3 - Agriculture, Forestry and Other Land Use	**1.4**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.3**	**1.4**	**1.4**	**1.4**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
3C - Aggregate Sources and Non-CO2 Emissions Sources on Land	***1.39***	***1.16***	***1.17***	***1.20***	***1.21***	***1.20***	***1.22***	***1.28***	***1.38***	***1.41***	***1.44***	***1.49***	***1.49***	***1.52***	***1.47***	***1.49***
3C1 - Emissions from Biomass Burning	**1.39**	**1.16**	**1.17**	**1.20**	**1.21**	**1.20**	**1.22**	**1.28**	**1.38**	**1.41**	**1.44**	**1.49**	**1.49**	**1.52**	**1.47**	**1.49**
3C1b - Biomass Burning in Croplands	1.39	1.16	1.17	1.20	1.21	1.20	1.22	1.28	1.38	1.41	1.44	1.49	1.49	1.52	1.47	1.49
4 - Waste	**7.1**	**7.5**	**7.8**	**7.9**	**8.0**	**8.3**	**8.5**	**8.7**	**8.9**	**9.1**	**9.3**	**9.4**	**9.6**	**9.7**	**9.8**	**10.0**
4A - Solid Waste Disposal	***6.28***	***6.62***	***6.88***	***6.86***	***6.90***	***7.08***	***7.28***	***7.39***	***7.47***	***7.57***	***7.68***	***7.73***	***7.87***	***7.91***	***7.95***	***8.00***
4A1 - Managed Waste Disposal Sites	**6.28**	**6.62**	**6.88**	**6.86**	**6.90**	**7.08**	**7.28**	**7.39**	**7.47**	**7.57**	**7.68**	**7.73**	**7.87**	**7.91**	**7.95**	**8.00**
4B - Biological Treatment of Solid Waste	***0.80***	***0.87***	***0.95***	***1.03***	***1.11***	***1.19***	***1.26***	***1.34***	***1.42***	***1.50***	***1.57***	***1.65***	***1.73***	***1.81***	***1.88***	***1.96***

California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category

million tonnes of CO2 equivalent - (based upon IPCC Fourth Assessment Report's 100-yr Global Warming Potentials)

CO2 from biogenic materials	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Summary for CO2 from biogenic material	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Carbon dioxide from Biogenic sources	25.0	25.5	24.2	27.3	29.0	28.8	28.9	29.0	29.5	31.5	34.0	35.6	35.7	41.2	41.0	39.6

California Greenhouse Gas Inventory for 2000-2015 — by IPCC Category

million tonnes of CO2 equivalent - (based upon IPCC Fourth Assessment Report's 100-yr Global Warming Potentials)

Forested Lands & Wood Products	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015

This section of the inventory is currently under development

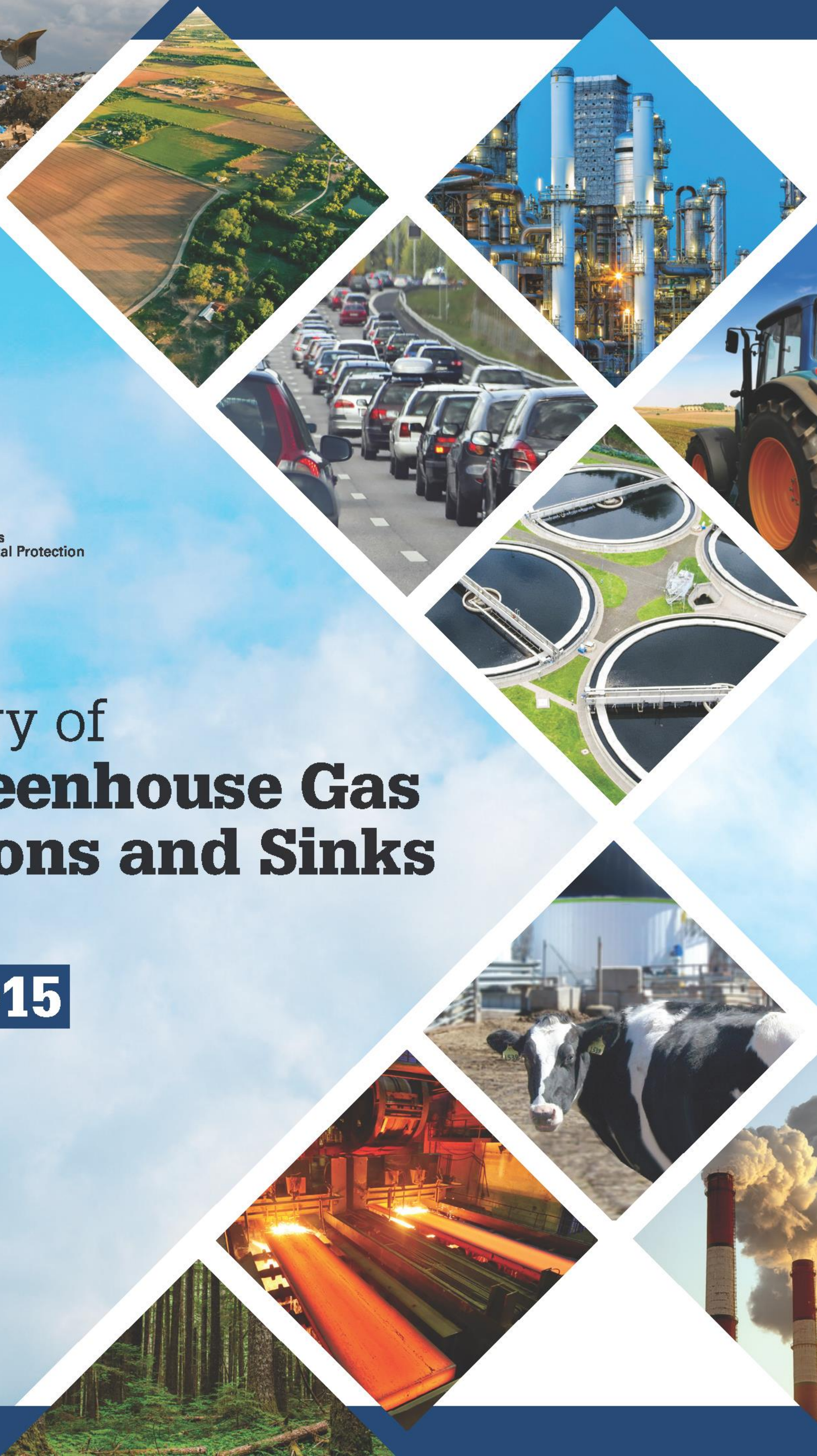
EXHIBIT 2

United States Environmental Protection Agency

EPA 430-P-17-001

Inventory of U.S. Greenhouse Gas Emissions and Sinks

1990–2015



Executive Summary

An emissions inventory that identifies and quantifies a country's primary anthropogenic[1] sources and sinks of greenhouse gases is essential for addressing climate change. This inventory adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and (2) a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contribution of different emission sources and greenhouse gases to climate change.

In 1992, the United States signed and ratified the UNFCCC. As stated in Article 2 of the UNFCCC, "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."[2]

Parties to the Convention, by ratifying, "shall develop, periodically update, publish and make available…national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies…"[3] The United States views this report as an opportunity to fulfill these commitments.

This chapter summarizes the latest information on U.S. anthropogenic greenhouse gas emission trends from 1990 through 2015. To ensure that the U.S. emissions inventory is comparable to those of other UNFCCC Parties, the estimates presented here were calculated using methodologies consistent with those recommended in the *2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* (IPCC 2006). The structure of this report is consistent with the UNFCCC guidelines for inventory reporting.[4]

Box ES-1: Methodological Approach for Estimating and Reporting U.S. Emissions and Sinks

In following the UNFCCC requirement under Article 4.1 to develop and submit national greenhouse gas emissions inventories, the gross emissions total presented in this report for the United States excludes emissions and sinks from land use, land-use change, and forestry (LULUCF). The net emissions total presented in this report for the United States includes emissions and sinks from LULUCF. All emissions and sinks are calculated using methods

[1] The term "anthropogenic," in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities (IPCC 2006).

[2] Article 2 of the Framework Convention on Climate Change published by the UNEP/WMO Information Unit on Climate Change. See <http://unfccc.int>.

[3] Article 4(1)(a) of the United Nations Framework Convention on Climate Change (also identified in Article 12). Subsequent decisions by the Conference of the Parties elaborated the role of Annex I Parties in preparing national inventories. See <http://unfccc.int>.

[4] See <http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf>.

that are consistent with internationally-accepted guidelines provided by the IPCC.[5] Additionally, the calculated emissions and sinks in a given year for the United States are presented in a common manner in line with the UNFCCC reporting guidelines for the reporting of inventories under this international agreement.[6] The use of consistent methods to calculate emissions and sinks by all nations providing their inventories to the UNFCCC ensures that these reports are comparable. The report itself follows this standardized format, and provides an explanation of the methods used to calculate emissions and sinks, and the manner in which those calculations are conducted.

Box ES-2: EPA's Greenhouse Gas Reporting Program

On October 30, 2009, the U.S. Environmental Protection Agency (EPA) published a rule for the mandatory reporting of greenhouse gases from large greenhouse gas emissions sources in the United States. Implementation of 40 CFR Part 98 is referred to as the Greenhouse Gas Reporting Program (GHGRP). 40 CFR part 98 applies to direct greenhouse gas emitters, fossil fuel suppliers, industrial gas suppliers, and facilities that inject carbon dioxide (CO_2) underground for sequestration or other reasons.[7] Reporting is at the facility level, except for certain suppliers of fossil fuels and industrial greenhouse gases. The GHGRP dataset and the data presented in this Inventory report are complementary.

The GHGRP dataset continues to be an important resource for the Inventory, providing not only annual emissions information, but also other annual information, such as activity data and emission factors that can improve and refine national emission estimates and trends over time. GHGRP data also allow EPA to disaggregate national inventory estimates in new ways that can highlight differences across regions and sub-categories of emissions, along with enhancing application of QA/QC procedures and assessment of uncertainties.

EPA uses annual GHGRP data in a number of category estimates and continues to analyze the data on an annual basis, as applicable, for further use to improve the national estimates presented in this Inventory consistent with IPCC guidance.[8]

ES.1 Background Information

Greenhouse gases absorb infrared radiation, thereby trapping heat and making the planet warmer. The most important greenhouse gases directly emitted by humans include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several other fluorine-containing halogenated substances. Although CO_2, CH_4, and N_2O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2015, concentrations of these greenhouse gases have increased globally by 44, 162, and 21 percent, respectively (IPCC 2013 and NOAA/ESRL 2017). This annual report estimates the total national greenhouse gas emissions and removals associated with human activities across the United States.

Global Warming Potentials

Gases in the atmosphere can contribute to climate change both directly and indirectly. Direct effects occur when the gas itself absorbs radiation. Indirect radiative forcing occurs when chemical transformations of the substance produce other greenhouse gases, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas

[5] See <http://www.ipcc-nggip.iges.or.jp/public/index.html>.

[6] See <http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf>.

[7] See <http://www.epa.gov/ghgreporting> and <http://ghgdata.epa.gov/ghgp/main.do>.

[8] See <http://www.ipcc-nggip.iges.or.jp/public/tb/TFI_Technical_Bulletin_1.pdf>

affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation or albedo).[9] The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas.

The GWP of a greenhouse gas is defined as the ratio of the accumulated radiative forcing within a specific time horizon caused by emitting 1 kilogram of the gas, relative to that of the reference gas CO_2 (IPCC 2014). The reference gas used is CO_2, and therefore GWP-weighted emissions are measured in million metric tons of CO_2 equivalent (MMT CO_2 Eq.).[10,11] All gases in this Executive Summary are presented in units of MMT CO_2 Eq. Emissions by gas in unweighted mass tons are provided in the Trends chapter of this report.

UNFCCC reporting guidelines for national inventories require the use of GWP values from the *IPCC Fourth Assessment Report* (AR4) (IPCC 2007).[12] All estimates are provided throughout the report in both CO_2 equivalents and unweighted units. A comparison of emission values using the AR4 GWP values versus the SAR (IPCC 1996), and the *IPCC Fifth Assessment Report* (AR5) (IPCC 2013) GWP values can be found in Chapter 1 and, in more detail, in Annex 6.1 of this report. The GWP values used in this report are listed below in Table ES-1.

Table ES-1: Global Warming Potentials (100-Year Time Horizon) Used in this Report

Gas	GWP
CO_2	1
CH_4[a]	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
HFC-4310mee	1,640
CF_4	7,390
C_2F_6	12,200
C_4F_{10}	8,860
C_6F_{14}	9,300
SF_6	22,800
NF_3	17,200

[a] The CH_4 GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to production of CO_2 is not included.
Source: IPCC (2007)

[9] Albedo is a measure of the Earth's reflectivity, and is defined as the fraction of the total solar radiation incident on a body that is reflected by it.

[10] Carbon comprises 12/44 of carbon dioxide by weight.

[11] One million metric ton is equal to 10^{12} grams or one teragram.

[12] See <http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf>.

ES.2 Recent Trends in U.S. Greenhouse Gas Emissions and Sinks

In 2015, total gross U.S. greenhouse gas emissions were 6,586.7 million metric tons (MMT) of CO_2 Eq. Total U.S. emissions have increased by 3.5 percent from 1990 to 2015, and emissions decreased from 2014 to 2015 by 2.3 percent (153.0 MMT CO_2 Eq.). The decrease in total greenhouse gas emissions between 2014 and 2015 was driven in large part by a decrease in CO_2 emissions from fossil fuel combustion. The decrease in CO_2 emissions from fossil fuel combustion was a result of multiple factors, including: (1) substitution from coal to natural gas consumption in the electric power sector; (2) warmer winter conditions in 2015 resulting in a decreased demand for heating fuel in the residential and commercial sectors; and (3) a slight decrease in electricity demand. Relative to 1990, the baseline for this Inventory, gross emissions in 2015 are higher by 3.5 percent, down from a high of 15.5 percent above 1990 levels in 2007. Figure ES-1 through Figure ES-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute change since 1990. Overall, net emissions in 2015 were 11.5 percent below 2005 levels as shown in Table ES-2.

Table ES-2 provides a detailed summary of gross U.S. greenhouse gas emissions and sinks for 1990 through 2015.

Figure ES-1: Gross U.S. Greenhouse Gas Emissions by Gas (MMT CO_2 Eq.)

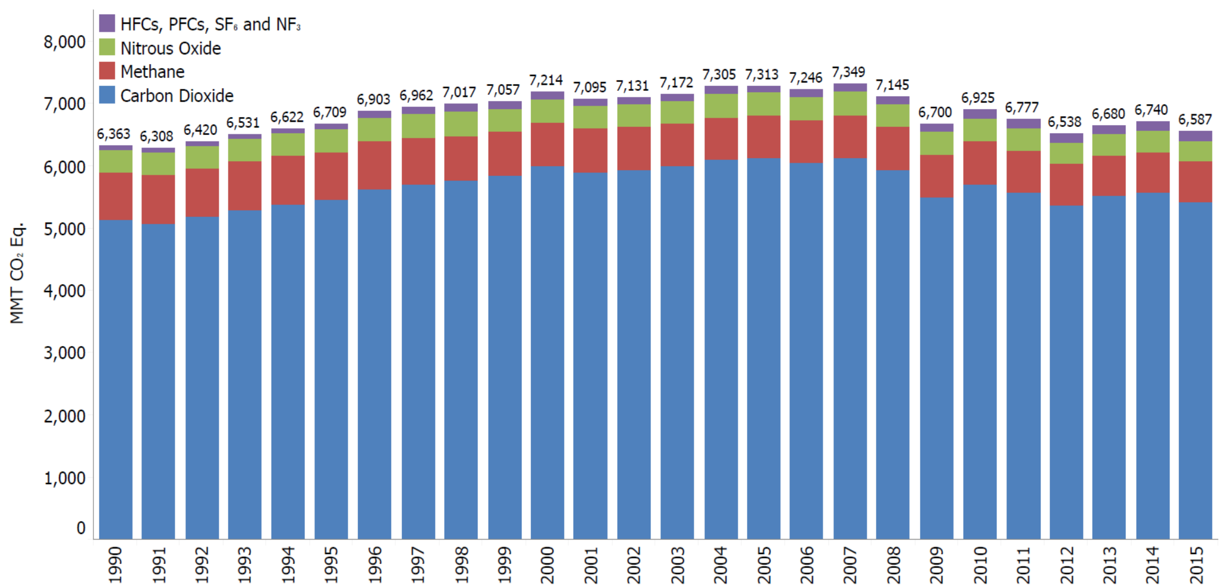


Figure ES-2: Annual Percent Change in Gross U.S. Greenhouse Gas Emissions Relative to the Previous Year

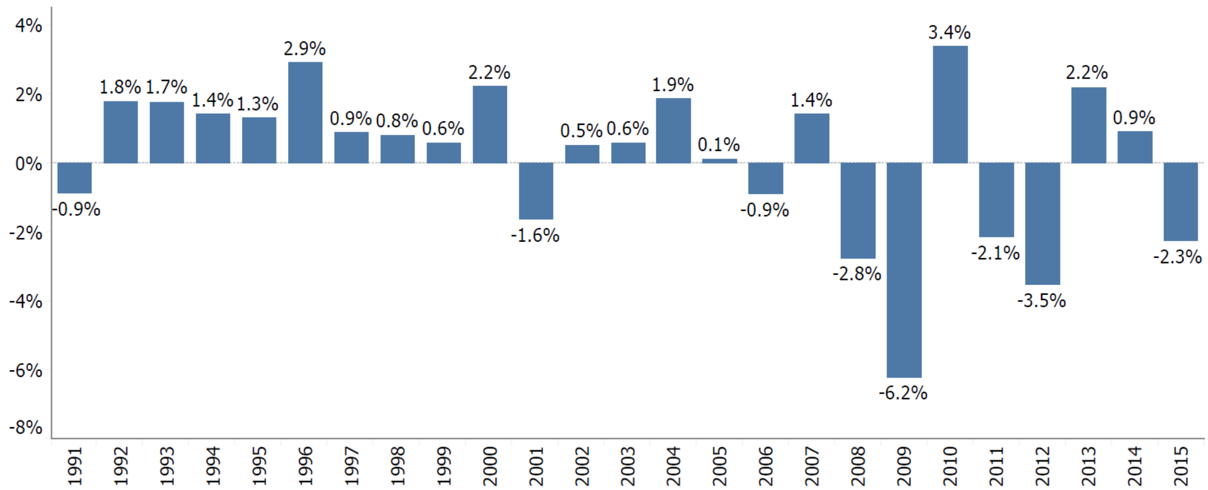


Figure ES-3: Cumulative Change in Annual Gross U.S. Greenhouse Gas Emissions Relative to 1990 (1990=0, MMT CO_2 Eq.)

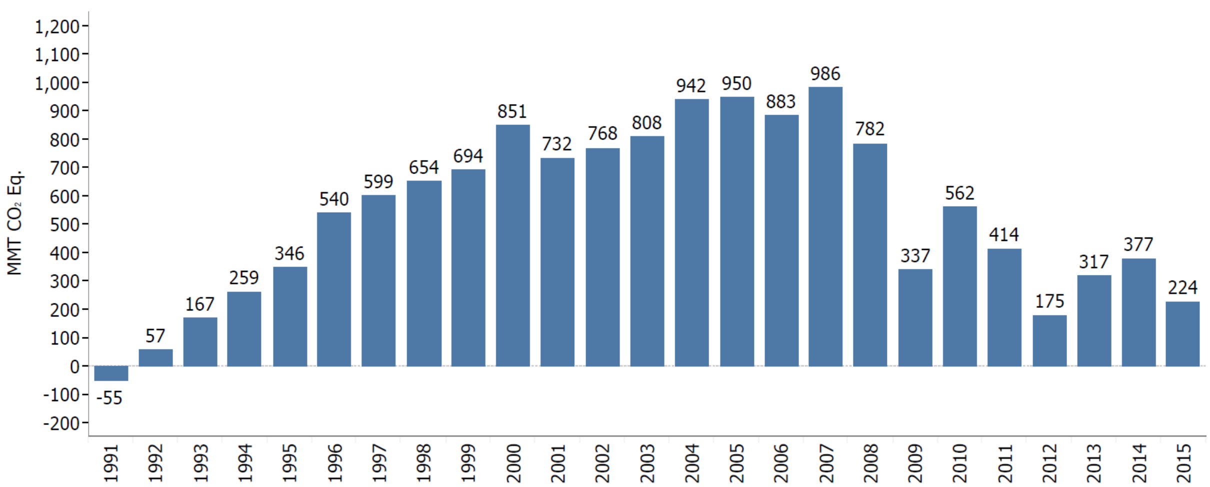


Table ES-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**5,123.0**	**6,131.8**	**5,569.5**	**5,362.1**	**5,514.0**	**5,565.5**	**5,411.4**
Fossil Fuel Combustion	4,740.3	5,746.9	5,227.1	5,024.6	5,156.5	5,202.3	5,049.8
Electricity Generation	*1,820.8*	*2,400.9*	*2,157.7*	*2,022.2*	*2,038.1*	*2,038.0*	*1,900.7*
Transportation[a]	*1,493.8*	*1,887.0*	*1,707.6*	*1,696.8*	*1,713.0*	*1,742.8*	*1,736.4*
Industrial[a]	*842.5*	*828.0*	*775.0*	*782.9*	*812.2*	*806.1*	*805.5*
Residential	*338.3*	*357.8*	*325.5*	*282.5*	*329.7*	*345.4*	*319.6*
Commercial[a]	*217.4*	*223.5*	*220.4*	*196.7*	*221.0*	*228.7*	*246.2*

U.S. Territories	*27.6*	*49.7*	*40.9*	*43.5*	*42.5*	*41.4*	*41.4*
Non-Energy Use of Fuels	117.6	138.9	109.8	106.7	123.6	119.0	125.5
Iron and Steel Production & Metallurgical Coke Production	101.5	68.0	61.1	55.4	53.3	58.6	48.9
Natural Gas Systems	37.7	30.1	35.7	35.2	38.5	42.4	42.4
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9
Petrochemical Production	21.3	27.0	26.3	26.5	26.4	26.5	28.1
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3
Other Process Uses of Carbonates	4.9	6.3	9.3	8.0	10.4	11.8	11.2
Ammonia Production	13.0	9.2	9.3	9.4	10.0	9.6	10.8
Incineration of Waste	8.0	12.5	10.6	10.4	10.4	10.6	10.7
Urea Fertilization	2.4	3.5	4.1	4.3	4.5	4.8	5.0
Carbon Dioxide Consumption	1.5	1.4	4.1	4.0	4.2	4.5	4.3
Liming	4.7	4.3	3.9	6.0	3.9	3.6	3.8
Petroleum Systems	3.6	3.9	4.2	3.9	3.7	3.6	3.6
Soda Ash Production and Consumption	2.8	3.0	2.7	2.8	2.8	2.8	2.8
Aluminum Production	6.8	4.1	3.3	3.4	3.3	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.9	1.8	1.9	2.0
Titanium Dioxide Production	1.2	1.8	1.7	1.5	1.7	1.7	1.6
Glass Production	1.5	1.9	1.3	1.2	1.3	1.3	1.3
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.0	4.4	4.0	1.4	1.1
Phosphoric Acid Production	1.5	1.3	1.2	1.1	1.1	1.0	1.0
Zinc Production	0.6	1.0	1.3	1.5	1.4	1.0	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Magnesium Production and Processing	+	+	+	+	+	+	+
Wood Biomass, Ethanol, and Biodiesel Consumption[b]	*219.4*	*230.7*	*276.4*	*276.2*	*299.8*	*307.1*	*291.7*
International Bunker Fuels[c]	*103.5*	*113.1*	*111.7*	*105.8*	*99.8*	*103.2*	*110.8*
CH_4	**780.8**	**680.9**	**672.1**	**666.1**	**658.8**	**659.1**	**655.7**
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5
Natural Gas Systems	194.1	159.7	154.5	156.2	159.2	162.5	162.4
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7
Manure Management	37.2	56.3	63.0	65.6	63.3	62.9	66.3
Coal Mining	96.5	64.1	71.2	66.5	64.6	64.8	60.9
Petroleum Systems	55.5	46.0	48.0	46.4	44.5	43.0	39.9
Wastewater Treatment	15.7	16.0	15.3	15.1	14.9	14.8	14.8
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2
Stationary Combustion	8.5	7.4	7.1	6.6	8.0	8.1	7.0
Abandoned Underground Coal Mines	7.2	6.6	6.4	6.2	6.2	6.3	6.4
Composting	0.4	1.9	1.9	1.9	2.0	2.1	2.1
Mobile Combustion[a]	5.6	2.8	2.3	2.2	2.1	2.1	2.0
Field Burning of Agricultural Residues	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Petrochemical Production	0.2	0.1	+	0.1	0.1	0.1	0.2
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+	+	+	+	+	+	+

Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**359.5**	**361.6**	**364.0**	**340.7**	**335.5**	**335.5**	**334.8**
Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3
Stationary Combustion	11.9	20.2	21.3	21.4	22.9	23.4	23.1
Manure Management	14.0	16.5	17.4	17.5	17.5	17.5	17.7
Mobile Combustion[a]	41.2	35.7	22.8	20.4	18.5	16.6	15.1
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6
Wastewater Treatment	3.4	4.4	4.8	4.8	4.9	4.9	5.0
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Composting	0.3	1.7	1.7	1.7	1.8	1.9	1.9
Incineration of Waste	0.5	0.4	0.3	0.3	0.3	0.3	0.3
Semiconductor Manufacture	+	0.1	0.2	0.2	0.2	0.2	0.2
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
International Bunker Fuels[c]	*0.9*	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.9*
HFCs	**46.6**	**120.0**	**154.3**	**155.9**	**159.0**	**166.7**	**173.2**
Substitution of Ozone Depleting Substances[d]	0.3	99.7	145.3	150.2	154.6	161.3	168.5
HCFC-22 Production	46.1	20.0	8.8	5.5	4.1	5.0	4.3
Semiconductor Manufacture	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Magnesium Production and Processing	0.0	0.0	+	+	0.1	0.1	0.1
PFCs	**24.3**	**6.7**	**6.9**	**6.0**	**5.8**	**5.8**	**5.2**
Semiconductor Manufacture	2.8	3.2	3.4	3.0	2.8	3.2	3.2
Aluminum Production	21.5	3.4	3.5	2.9	3.0	2.5	2.0
Substitution of Ozone Depleting Substances	0.0	+	+	+	+	+	+
SF_6	**28.8**	**11.7**	**9.2**	**6.8**	**6.4**	**6.6**	**5.8**
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2
Magnesium Production and Processing	5.2	2.7	2.8	1.6	1.5	1.0	0.9
Semiconductor Manufacture	0.5	0.7	0.4	0.4	0.4	0.7	0.7
NF_3	**+**	**0.5**	**0.7**	**0.6**	**0.6**	**0.5**	**0.6**
Semiconductor Manufacture	+	0.5	0.7	0.6	0.6	0.5	0.6
Total Emissions	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**
LULUCF Emissions[e]	**10.6**	**23.0**	**19.9**	**26.1**	**19.2**	**19.7**	**19.7**
LULUCF Carbon Stock Change[f]	**(830.2)**	**(754.0)**	**(769.1)**	**(779.8)**	**(782.2)**	**(781.1)**	**(778.7)**
LULUCF Sector Net Total[g]	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**
Net Emissions (Sources and Sinks)	**5,543.5**	**6,582.3**	**6,027.6**	**5,784.5**	**5,917.1**	**5,978.3**	**5,827.7**

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF.

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

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

[d] Small amounts of PFC emissions also result from this source.

[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*; and N_2O emissions from Forest Soils and Settlement Soils.

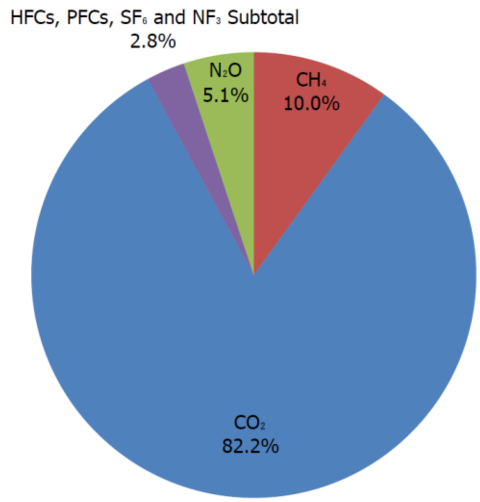
[f] LULUCF Carbon Stock Change is the net C stock change from the following categories: *Forest Land Remaining Forest Land, Land Converted to Forest Land, Cropland Remaining Cropland, Land Converted to Cropland, Grassland Remaining Grassland, Land Converted to Grassland, Wetlands Remaining Wetlands, Land Converted to Wetlands, Settlements Remaining Settlements*, and *Land Converted to Settlements*. Refer to Table ES-5 for a breakout of emissions and removals for Land Use, Land-Use Change, and Forestry by gas and source category.

[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 negative values or sequestration.

Figure ES-4 illustrates the relative contribution of the direct greenhouse gases to total U.S. emissions in 2015, weighted by global warming potential. Note, unless otherwise stated, all tables and figures provide total emissions without LULUCF. The primary greenhouse gas emitted by human activities in the United States was CO_2, representing approximately 82.2 percent of total greenhouse gas emissions. The largest source of CO_2, and of overall greenhouse gas emissions, was fossil fuel combustion. Methane emissions, which have decreased by 16.0 percent since 1990, resulted primarily from enteric fermentation associated with domestic livestock, natural gas systems, and decomposition of wastes in landfills. Agricultural soil management, manure management, mobile source fuel combustion and stationary fuel combustion were the major sources of N_2O emissions. Ozone depleting substance substitute emissions and emissions of HFC-23 during the production of HCFC-22 were the primary contributors to aggregate hydrofluorocarbon (HFC) emissions. Perfluorocarbon (PFC) emissions resulted as a byproduct of primary aluminum production and from semiconductor manufacturing, electrical transmission and distribution systems accounted for most sulfur hexafluoride (SF_6) emissions, and semiconductor manufacturing is the only source of nitrogen trifluoride (NF_3) emissions.

Figure ES-4: 2015 U.S. Greenhouse Gas Emissions by Gas (Percentages based on MMT CO_2 Eq.)



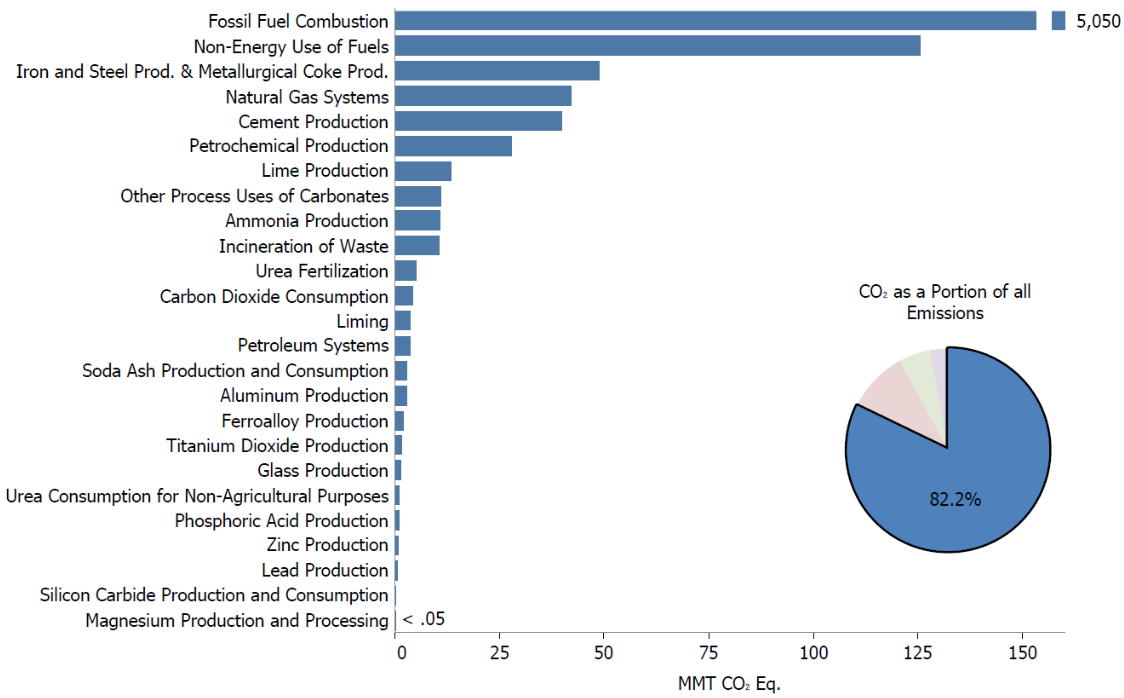
Overall, from 1990 to 2015, total emissions of CO_2 increased by 288.4 MMT CO_2 Eq. (5.6 percent), while total emissions of CH_4 decreased by 125.1 MMT CO_2 Eq. (16.0 percent), and N_2O emissions decreased by 24.7 MMT CO_2 Eq. (6.9 percent). During the same period, aggregate weighted emissions of HFCs, PFCs, SF_6 and NF_3 rose by 85.0 MMT CO_2 Eq. (85.3 percent). From 1990 to 2015, HFCs increased by 126.6 MMT CO_2 Eq. (271.8 percent), PFCs decreased by 19.1 MMT CO_2 Eq. (78.6 percent), SF_6 decreased by 23.0 MMT CO_2 Eq. (79.8 percent), and NF_3 increased by 0.5 MMT CO_2 Eq. (1,057.0 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, SF_6 and NF_3 are significant because many of these gases have extremely high global warming potentials and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon (C) sequestration in forests, trees in urban areas, agricultural soils, landfilled yard trimmings and food scraps, and coastal wetlands, which, in aggregate, offset

11.8 percent of total emissions in 2015. The following sections describe each gas's contribution to total U.S. greenhouse gas emissions in more detail.

Carbon Dioxide Emissions

The global carbon cycle is made up of large carbon flows and reservoirs. Billions of tons of carbon in the form of CO_2 are absorbed by oceans and living biomass (i.e., sinks) and are emitted to the atmosphere annually through natural processes (i.e., sources). When in equilibrium, carbon fluxes among these various reservoirs are roughly balanced.[13] Since the Industrial Revolution (i.e., about 1750), global atmospheric concentrations of CO_2 have risen approximately 44 percent (IPCC 2013 and NOAA/ESRL 2017), principally due to the combustion of fossil fuels. Within the United States, fossil fuel combustion accounted for 93.3 percent of CO_2 emissions in 2015. Globally, approximately 33,733 MMT of CO_2 were added to the atmosphere through the combustion of fossil fuels in 2014, of which the United States accounted for approximately 16 percent.[14] Changes in land use and forestry practices can lead to net CO_2 emissions (e.g., through conversion of forest land to agricultural or urban use) or to a net sink for CO_2 (e.g., through net additions to forest biomass). Fossil fuel combustion is the greatest source of CO_2 emissions. There are 24 additional sources included in the Inventory (Figure ES-5).

Figure ES-5: 2015 Sources of CO_2 Emissions (MMT CO_2 Eq.)



Note: Fossil Fuel Combustion includes electricity generation, which also includes emissions of less than 0.05 MMT CO_2 Eq. from geothermal-based generation.

As the largest source of U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 77 percent of GWP-weighted emissions since 1990. The fundamental factors influencing emissions levels include (1) changes in demand for energy and (2) a general decline in the carbon intensity of fuels combusted for energy in recent years by most sectors of the economy. Between 1990 and 2015, CO_2 emissions from fossil fuel

[13] The term "flux" is used to describe the net emissions of greenhouse gases accounting for both the emissions of CO_2 to and the removals of CO_2 from the atmosphere. Removal of CO_2 from the atmosphere is also referred to as "carbon sequestration."

[14] Global CO_2 emissions from fossil fuel combustion were taken from International Energy Agency *CO_2 Emissions from Fossil Fuels Combustion – Highlights* IEA (2016). See <https://www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion-highlights-2016.html>.

combustion increased from 4,740.3 MMT CO_2 Eq. to 5,049.8 MMT CO_2 Eq., a 6.5 percent total increase over the twenty-six-year period. In addition, CO_2 emissions from fossil fuel combustion decreased by 697.2 MMT CO_2 Eq. from 2005 levels, a decrease of approximately 12.1 percent between 2005 and 2015. From 2014 to 2015, these emissions decreased by 152.5 MMT CO_2 Eq. (2.9 percent).

Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors. Long-term factors include population and economic trends, technological changes, shifting energy fuel choices, and various policies at the national, state, and local level. In the short term, the overall consumption and mix of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, overall energy prices, the relative price of different fuels, weather, and the availability of non-fossil alternatives.

Figure ES-6: 2015 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type (MMT CO_2 Eq.)

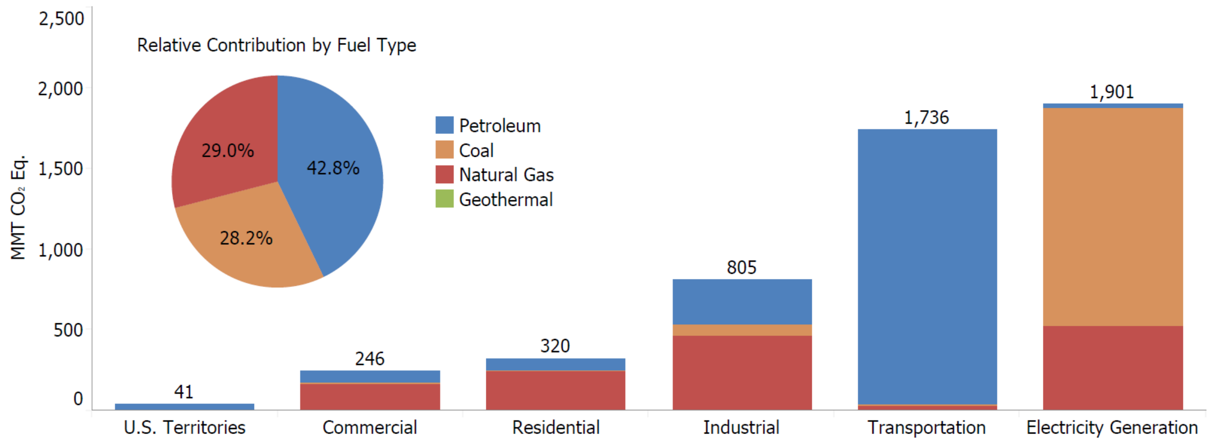
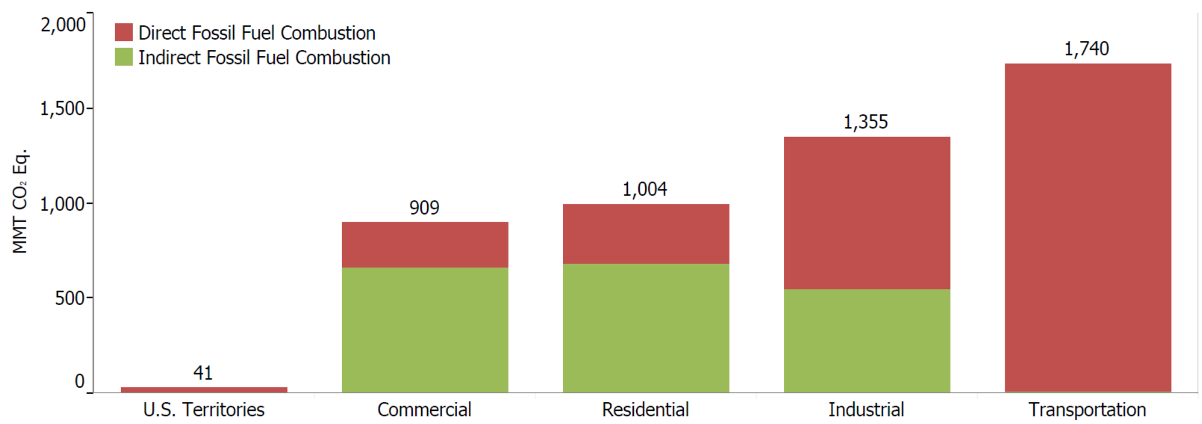


Figure ES-7: 2015 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion (MMT CO_2 Eq.)



The five major fuel consuming economic sectors contributing to CO_2 emissions from fossil fuel combustion are electricity generation, transportation, industrial, residential, and commercial. Carbon dioxide emissions are produced by the electricity generation sector as they consume fossil fuel to provide electricity to one of the other four sectors, or "end-use" sectors. For the discussion below, electricity generation emissions have been distributed to each end-use sector on the basis of each sector's share of aggregate electricity consumption. This method of distributing emissions assumes that each end-use sector consumes electricity that is generated from the national average mix of fuels according to their carbon intensity. Emissions from electricity generation are also addressed separately after the end-use sectors have been discussed.

Note that emissions from U.S. Territories are calculated separately due to a lack of specific consumption data for the individual end-use sectors. Figure ES-6, Figure ES-7, and Table ES-3 summarize CO_2 emissions from fossil fuel combustion by end-use sector.

Table ES-3: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (MMT CO_2 Eq.)

End-Use Sector	1990	2005	2011	2012	2013	2014	2015
Transportation[a]	**1,496.8**	**1,891.8**	**1,711.9**	**1,700.6**	**1,717.0**	**1,746.9**	**1,740.1**
Combustion	1,493.8	1,887.0	1,707.6	1,696.8	1,713.0	1,742.8	1,736.4
Electricity	3.0	4.7	4.3	3.9	4.0	4.1	3.7
Industrial[a]	**1,529.2**	**1,564.6**	**1,399.6**	**1,375.7**	**1,407.0**	**1,399.3**	**1,355.0**
Combustion	842.5	828.0	775.0	782.9	812.2	806.1	805.5
Electricity	686.7	736.6	624.7	592.8	594.7	593.2	549.6
Residential	**931.4**	**1,214.1**	**1,116.2**	**1,007.8**	**1,064.6**	**1,080.1**	**1,003.9**
Combustion	338.3	357.8	325.5	282.5	329.7	345.4	319.6
Electricity	593.0	856.3	790.7	725.3	734.9	734.7	684.3
Commercial[a]	**755.4**	**1,026.8**	**958.4**	**897.0**	**925.5**	**934.7**	**909.4**
Combustion	217.4	223.5	220.4	196.7	221.0	228.7	246.2
Electricity	538.0	803.3	738.0	700.3	704.5	706.0	663.1
U.S. Territories[b]	**27.6**	**49.7**	**40.9**	**43.5**	**42.5**	**41.4**	**41.4**
Total	**4,740.3**	**5,746.9**	**5,227.1**	**5,024.6**	**5,156.5**	**5,202.3**	**5,049.8**
Electricity Generation	**1,820.8**	**2,400.9**	**2,157.7**	**2,022.2**	**2,038.1**	**2,038.0**	**1,900.7**

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Fuel consumption by U.S. Territories (i.e., American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other U.S. Pacific Islands) is included in this report.

Notes: Combustion-related emissions from electricity generation are allocated based on aggregate national electricity consumption by each end-use sector. Totals may not sum due to independent rounding.

Transportation End-Use Sector. When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 34.5 percent of U.S. CO_2 emissions from fossil fuel combustion in 2015.The largest sources of transportation CO_2 emissions in 2015 were passenger cars (42.3 percent), medium- and heavy-duty trucks (23.6 percent), light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (17.1 percent), commercial aircraft (6.8 percent), rail (2.5 percent), other aircraft (2.3 percent), pipelines (2.2 percent), and ships and boats (1.9 percent). Annex 3.2 presents the total emissions from all transportation and mobile sources, including CO_2, CH_4, N_2O, and HFCs.

In terms of the overall trend, from 1990 to 2015, total transportation CO_2 emissions increased due, in large part, to increased demand for travel. The number of VMT by light-duty motor vehicles (i.e., passenger cars and light-duty trucks) increased 40 percent from 1990 to 2015,[15] as a result of a confluence of factors including population growth, economic growth, urban sprawl, and low fuel prices during the beginning of this period. Almost all of the energy consumed for transportation was supplied by petroleum-based products, with more than half being related to

[15] VMT estimates are based on data from FHWA Highway Statistics Table VM-1 (FHWA 1996 through 2016). In 2011, FHWA changed its methods for estimating VMT by vehicle class, which led to a shift in VMT and emissions among on-road vehicle classes in the 2007 to 2015 time period. In absence of these method changes, light-duty VMT growth between 1990 and 2015 would likely have been even higher.

gasoline consumption in automobiles and other highway vehicles. Other fuel uses, especially diesel fuel for freight trucks and jet fuel for aircraft, accounted for the remainder.

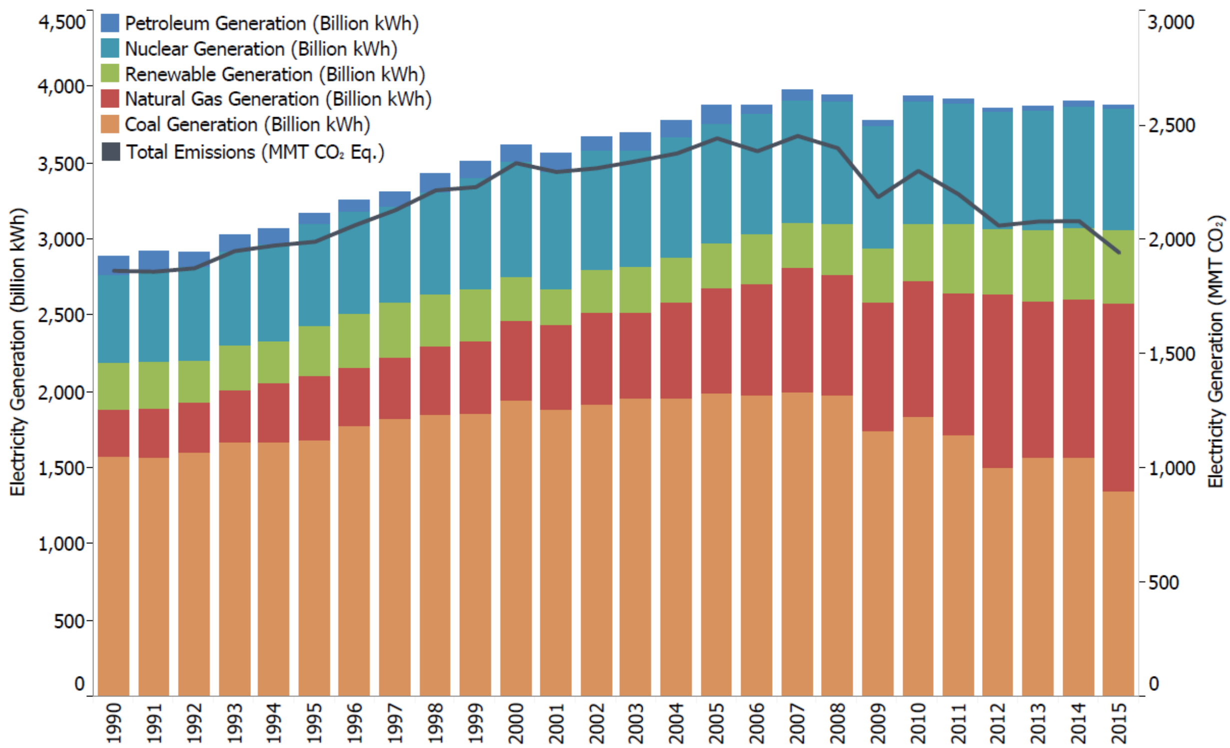
Industrial End-Use Sector. Industrial CO_2 emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity that is consumed by industry, accounted for 27 percent of CO_2 from fossil fuel combustion in 2015. Approximately 59 percent of these emissions resulted from direct fossil fuel combustion to produce steam and/or heat for industrial processes. The remaining emissions resulted from consuming electricity for motors, electric furnaces, ovens, lighting, and other applications. In contrast to the other end-use sectors, emissions from industry have declined since 1990. This decline is due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements.

Residential and Commercial End-Use Sectors. The residential and commercial end-use sectors accounted for 20 and 18 percent, respectively, of CO_2 emissions from fossil fuel combustion in 2015. Both sectors relied heavily on electricity for meeting energy demands, with 68 and 73 percent, respectively, of their emissions attributable to electricity consumption for lighting, heating, cooling, and operating appliances. The remaining emissions were due to the consumption of natural gas and petroleum for heating and cooking. Emissions from the residential and commercial end-use sectors have increased by 8 percent and 20 percent since 1990, respectively.

Electricity Generation. The United States relies on electricity to meet a significant portion of its energy demands. Electricity generators consumed 34 percent of total U.S. energy uses from fossil fuels and emitted 38 percent of the CO_2 from fossil fuel combustion in 2015. The type of energy source used to generate electricity is the main factor influencing emissions. For example, some electricity is generated through non-fossil fuel options such as nuclear, hydroelectric, or geothermal energy. Including all electricity generation modes, electricity generators relied on coal for approximately 34 percent of their total energy requirements in 2015. In addition, the coal used by electricity generators accounted for 93 percent of all coal consumed for energy in the United States in 2015.[16] Recently, a decrease in the carbon intensity of fuels consumed to generate electricity has occurred due to a decrease in coal consumption, and increased natural gas consumption and other generation sources. Including all electricity generation modes, electricity generators used natural gas for approximately 32 percent of their total energy requirements in 2015. Across the time series, changes in electricity demand and the carbon intensity of fuels used for electricity generation have a significant impact on CO_2 emissions. While emissions from the electric power sector have increased by approximately 4 percent since 1990, the carbon intensity of the electric power sector, in terms of CO_2 Eq. per QBtu has significantly decreased by 16 percent during that same timeframe. This trend away from a direct relationship between electricity generation and the resulting emissions is shown below in Figure ES-8.

[16] See Table 6.2 Coal Consumption by Sector of EIA 2016.

Figure ES-8: Electricity Generation (Billion kWh) and Electricity Generation Emissions (MMT CO_2 Eq.)



Other significant CO_2 trends included the following:

- Carbon dioxide emissions from non-energy use of fossil fuels increased by 7.9 MMT CO_2 Eq. (6.8 percent) from 1990 through 2015. Emissions from non-energy uses of fossil fuels were 125.5 MMT CO_2 Eq. in 2015, which constituted 2.3 percent of total national CO_2 emissions, approximately the same proportion as in 1990.
- Carbon dioxide emissions from iron and steel production and metallurgical coke production have decreased by 52.6 MMT CO_2 Eq. (51.8 percent) from 1990 through 2015, due to restructuring of the industry, technological improvements, and increased scrap steel utilization.
- Carbon dioxide emissions from ammonia production (10.8 MMT CO_2 Eq. in 2015) decreased by 2.2 MMT CO_2 Eq. (17.2 percent) since 1990. Ammonia production relies on natural gas as both a feedstock and a fuel, and as such, market fluctuations and volatility in natural gas prices affect the production of ammonia.
- Total C stock change (i.e., net CO_2 removals) in the LULUCF sector decreased by approximately 6.2 percent between 1990 and 2015. This decrease was primarily due to a decrease in the rate of net C accumulation in forest C stocks and an increase in emissions from *Land Converted to Settlements*.

Box ES-3: Use of Ambient Measurements Systems for Validation of Emission Inventories

In following the UNFCCC requirement under Article 4.1 to develop and submit national greenhouse gas emission inventories, the emissions and sinks presented in this report are organized by source and sink categories and calculated using internationally-accepted methods provided by the IPCC.[17] Several recent studies have measured

[17] See <http://www.ipcc-nggip.iges.or.jp/public/index.html>.

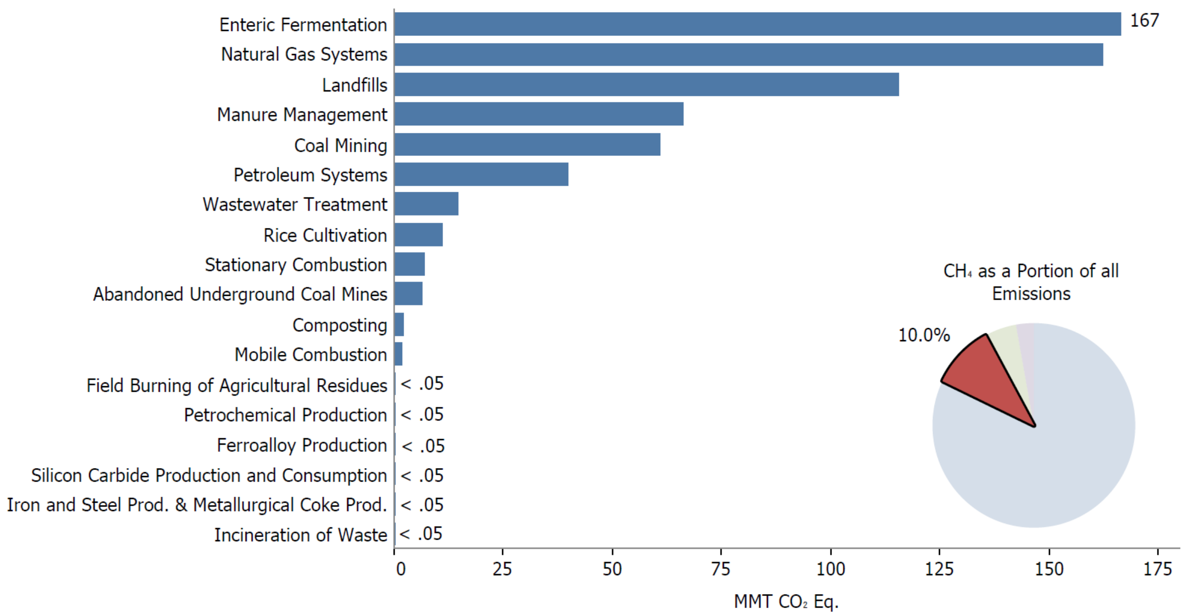
emissions at the national or regional level with results that sometimes differ from EPA's estimate of emissions. EPA has engaged with researchers on how remote sensing, ambient measurement, and inverse modeling techniques for greenhouse gas emissions could assist in improving the understanding of inventory estimates. In working with the research community on ambient measurement and remote sensing techniques to improve national greenhouse gas inventories, EPA follows guidance from the IPCC on the use of measurements and modeling to validate emission inventories.[18] An area of particular interest in EPA's outreach efforts is how ambient measurement data can be used in a manner consistent with this Inventory report's transparency on its calculation methodologies, and the ability of these techniques to attribute emissions and removals from remote sensing to anthropogenic sources, as defined by the IPCC for this report, versus natural sources and sinks.

In an effort to improve the ability to compare the national-level greenhouse gas inventory with measurement results that may be at other scales, a team at Harvard University along with EPA and other coauthors developed a gridded inventory of U.S. anthropogenic methane emissions with 0.1° x 0.1° spatial resolution, monthly temporal resolution, and detailed scale-dependent error characterization. The Inventory is designed to be consistent with the 1990 to 2014 U.S. EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks* estimates for the year 2012, which presents national totals for different source types.[19]

Methane Emissions

Methane (CH_4) is 25 times as effective as CO_2 at trapping heat in the atmosphere (IPCC 2007). Over the last two hundred and fifty years, the concentration of CH_4 in the atmosphere increased by 162 percent (IPCC 2013 and CDIAC 2016). Anthropogenic sources of CH_4 include natural gas and petroleum systems, agricultural activities, LULUCF, landfills, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (see Figure ES-9).

Figure ES-9: 2015 Sources of CH_4 Emissions (MMT CO_2 Eq.)



Note: LULUCF emissions are reported separately from gross emissions totals and are not included in Figure ES-9. Refer to Table ES-5 for a breakout of LULUCF emissions by gas.

[18] See <http://www.ipcc-nggip.iges.or.jp/meeting/pdffiles/1003_Uncertainty%20meeting_report.pdf>.

[19] See <https://www.epa.gov/ghgemissions/gridded-2012-methane-emissions>.

Some significant trends in U.S. emissions of CH_4 include the following:

- Enteric fermentation is the largest anthropogenic source of CH_4 emissions in the United States. In 2015, enteric fermentation CH_4 emissions were 166.5 MMT CO_2 Eq. (25.4 percent of total CH_4 emissions), which represents an increase of 2.4 MMT CO_2 Eq. (1.5 percent) since 1990. This increase in emissions from 1990 to 2015 generally follows the increasing trends in cattle populations. From 1990 to 1995, emissions increased and then generally decreased from 1996 to 2004, mainly due to fluctuations in beef cattle populations and increased digestibility of feed for feedlot cattle. Emissions increased from 2005 to 2007, as both dairy and beef populations increased. Research indicates that the feed digestibility of dairy cow diets decreased during this period. Emissions decreased again from 2008 to 2015 as beef cattle populations again decreased.

- Natural gas systems were the second largest anthropogenic source category of CH_4 emissions in the United States in 2015 with 162.4 MMT CO_2 Eq. of CH_4 emitted into the atmosphere. Those emissions have decreased by 31.6 MMT CO_2 Eq. (16.3 percent) since 1990. The decrease in CH_4 emissions is largely due to the decrease in emissions from transmission, storage, and distribution. The decrease in transmission and storage emissions is largely due to reduced compressor station emissions (including emissions from compressors and fugitives). The decrease in distribution emissions is largely attributed to increased use of plastic piping, which has lower emissions than other pipe materials, and station upgrades at metering and regulating (M&R) stations.

- Landfills are the third largest anthropogenic source of CH_4 emissions in the United States (115.7 MMT CO_2 Eq.), accounting for 17.6 percent of total CH_4 emissions in 2015. From 1990 to 2015, CH_4 emissions from landfills decreased by 63.8 MMT CO_2 Eq. (35.6 percent), with small increases occurring in some interim years. This downward trend in emissions coincided with increased landfill gas collection and control systems, and a reduction of decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in MSW landfills over the time series,[20] which has more than offset the additional CH_4 emissions that would have resulted from an increase in the amount of municipal solid waste landfilled.

- Methane emissions from manure management, the fourth largest anthropogenic source of CH_4 emissions in the United States, increased by 78.3 percent since 1990, from 37.2 MMT CO_2 Eq. in 1990 to 66.3 MMT CO_2 Eq. in 2015. The majority of this increase was from swine and dairy cow manure, since the general trend in manure management is one of increasing use of liquid systems, which tends to produce greater CH_4 emissions. The increase in liquid systems is the combined result of a shift to larger facilities, and to facilities in the West and Southwest, all of which tend to use liquid systems. Also, new regulations limiting the application of manure nutrients have shifted manure management practices at smaller dairies from daily spread to manure managed and stored on site.

- Methane emissions from petroleum systems in the United States (39.9 MMT CO_2 Eq.) accounted for 6.1 percent of total CH_4 emissions in 2015. From 1990 to 2015, CH_4 emissions from petroleum systems decreased by 15.6 MMT CO_2 Eq. (or 28.1 percent). Production segment CH_4 emissions have decreased by around 8 percent from 2014 levels, primarily due to decreases in emissions from associated gas venting and flaring.

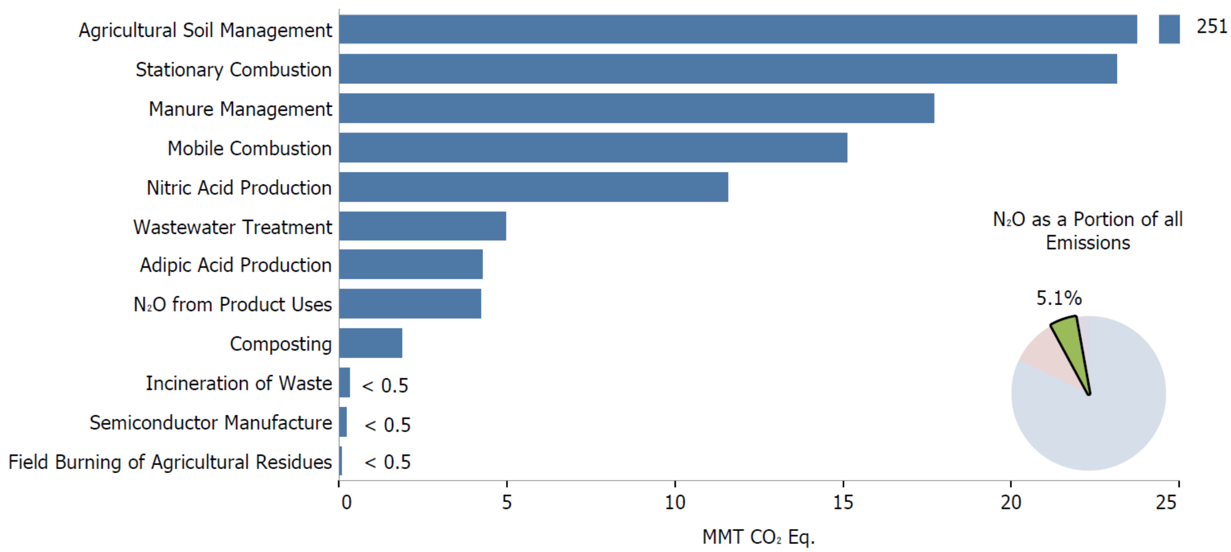
Nitrous Oxide Emissions

Nitrous oxide (N_2O) is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in the agricultural, energy-related, industrial, and waste management fields. While total N_2O emissions are much lower than CO_2 emissions, N_2O is nearly 300 times more powerful than CO_2 at trapping heat in the atmosphere (IPCC 2007). Since 1750, the global atmospheric concentration of N_2O has risen by approximately 21 percent (IPCC 2013 and CDIAC 2016). The main anthropogenic activities producing N_2O in the United States

[20] Carbon dioxide emissions from landfills are not included specifically in summing waste sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs and disposed wood products are accounted for in the estimates for LULUCF.

are agricultural soil management, stationary fuel combustion, fuel combustion in motor vehicles, manure management, and nitric acid production (see Figure ES-10).

Figure ES-10: 2015 Sources of N_2O Emissions (MMT CO_2 Eq.)



Note: LULUCF emissions are reported separately from gross emissions totals and are not included in Figure ES-10. Refer to Table ES-5 for a breakout of LULUCF emissions by gas.

Some significant trends in U.S. emissions of N_2O include the following:

- Agricultural soils accounted for approximately 75.1 percent of N_2O emissions and 3.8 percent of total emissions in the United States in 2015. Estimated emissions from this source in 2015 were 251.3 MMT CO_2 Eq. Annual N_2O emissions from agricultural soils fluctuated between 1990 and 2015, although overall emissions were 2.0 percent lower in 2015 than in 1990. Year-to-year fluctuations are largely a reflection of annual variation in weather patterns, synthetic fertilizer use, and crop production.
- Nitrous oxide emissions from stationary combustion increased 11.2 MMT CO_2 Eq. (94.0 percent) from 1990 through 2015. Nitrous oxide emissions from this source increased primarily as a result of an increase in the number of coal fluidized bed boilers in the electric power sector.
- In 2015, total N_2O emissions from manure management were estimated to be 17.7 MMT CO_2 Eq.; emissions were 14.0 MMT CO_2 Eq. in 1990. These values include both direct and indirect N_2O emissions from manure management. Nitrous oxide emissions have remained fairly steady since 1990. Small changes in N_2O emissions from individual animal groups exhibit the same trends as the animal group populations, with the overall net effect that N_2O emissions showed a 26.6 percent increase from 1990 to 2015 and a 1.1 percent increase from 2014 through 2015.
- Nitrous oxide emissions from mobile combustion decreased by 26.1 MMT CO_2 Eq. (63.3 percent) from 1990 through 2015, primarily as a result of N_2O national emission control standards and emission control technologies for on-road vehicles.
- Nitrous oxide emissions from adipic acid production were 4.3 MMT CO_2 Eq. in 2015, and have decreased significantly since 1990 due to both the widespread installation of pollution control measures in the late 1990s and plant idling in the late 2000s. Emissions from adipic acid production have decreased by 72.0 percent since 1990 and by 74.8 percent since a peak in 1995.

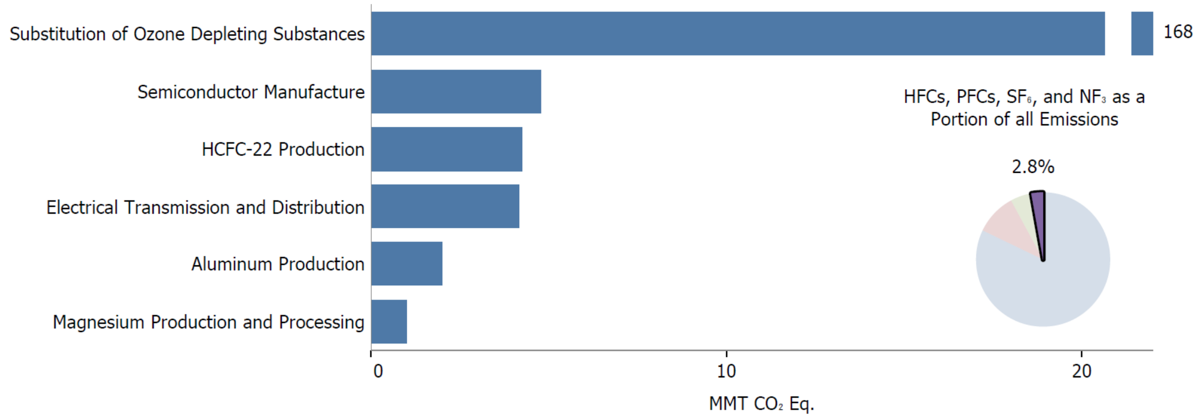
HFC, PFC, SF_6, and NF_3 Emissions

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are families of synthetic chemicals that are used as alternatives to ozone depleting substances (ODS), which are being phased out under the Montreal Protocol and Clean Air Act Amendments of 1990. Hydrofluorocarbons and PFCs do not deplete the stratospheric ozone layer, and are therefore acceptable alternatives under the Montreal Protocol on Substances that Deplete the Ozone Layer.

These compounds, however, along with SF_6 and NF_3, are potent greenhouse gases. In addition to having high global warming potentials, SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted. Sulfur hexafluoride is the most potent greenhouse gas the IPCC has evaluated (IPCC 2013).

Other emissive sources of these gases include HCFC-22 production, electrical transmission and distribution systems, semiconductor manufacturing, aluminum production, and magnesium production and processing (see Figure ES-11).

Figure ES-11: 2015 Sources of HFCs, PFCs, SF_6, and NF_3 Emissions (MMT CO_2 Eq.)



Some significant trends in U.S. HFC, PFC, SF_6, and NF_3 emissions include the following:

- Hydrofluorocarbon and perfluorocarbon emissions resulting from the substitution of ODS (e.g., chlorofluorocarbons [CFCs]) have been consistently increasing, from small amounts in 1990 to 168.5 MMT CO_2 Eq. in 2015. This increase was in large part the result of efforts to phase out CFCs and other ODS in the United States. In the short term, this trend is expected to continue, and will likely continue over the next decade as hydrochlorofluorocarbons (HCFCs), which are interim substitutes in many applications, are themselves phased out under the provisions of the Copenhagen Amendments to the Montreal Protocol.
- GWP-weighted PFC, HFC, SF_6, and NF_3 emissions from semiconductor manufacturing have increased by 34.3 percent from 1990 to 2015, due to industrial growth and the adoption of emission reduction technologies. Within that time span, emissions peaked in 1999, the initial year of EPA's PFC Reduction/Climate Partnership for the Semiconductor Industry, but have since declined to 4.8 MMT CO_2 Eq. in 2015 (a 47.1 percent decrease relative to 1999).
- Sulfur hexafluoride emissions from electric power transmission and distribution systems decreased by 82.0 percent (19.0 MMT CO_2 Eq.) from 1990 to 2015. There are two potential causes for this decrease: (1) a sharp increase in the price of SF_6 during the 1990s and (2) a growing awareness of the environmental impact of SF_6 emissions through programs such as EPA's SF_6 Emission Reduction Partnership for Electric Power Systems.
- Perfluorocarbon emissions from aluminum production decreased by 90.7 percent (19.5 MMT CO_2 Eq.) from 1990 to 2015. This decline is due both to reductions in domestic aluminum production and to actions taken by aluminum smelting companies to reduce the frequency and duration of anode effects.

ES.3 Overview of Sector Emissions and Trends

In accordance with the UNFCCC decision to set the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006) as the standard for Annex I countries at the Nineteenth Conference of the Parties (UNFCCC 2014), Figure ES-12 and Table ES-4 aggregate emissions and sinks by the sectors defined by those guidelines. Over the twenty-six-year period of 1990 to 2015, total emissions in the Energy, Industrial Processes and Product Use, and Agriculture grew by 221.0 MMT CO_2 Eq. (4.1 percent), 35.5 MMT CO_2 Eq. (10.4 percent), and 27.0 MMT CO_2 Eq. (5.5 percent), respectively. Over the same period, total emissions in the Waste sector decreased by 59.9 MMT CO_2 Eq. (30.1 percent) and estimates of net C sequestration in the LULUCF sector (magnitude of emissions plus CO_2 removals from all LULUCF source categories) decreased by 60.7 MMT CO_2 Eq. (7.4 percent).

Figure ES-12: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO_2 Eq.)

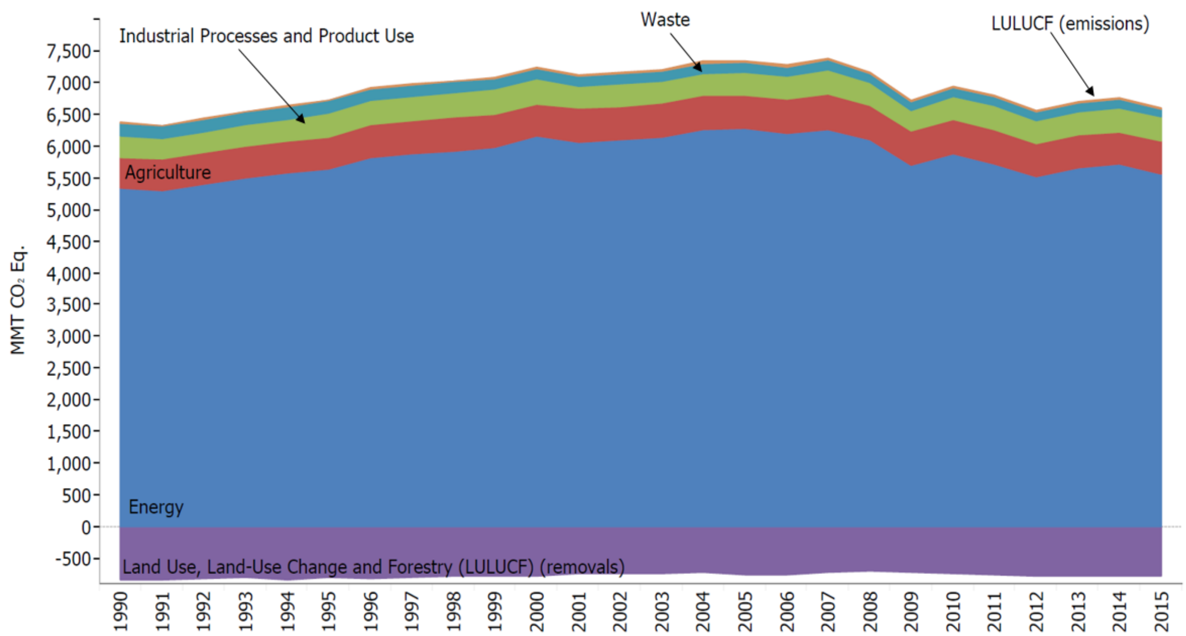


Table ES-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO_2 Eq.)

Chapter/IPCC Sector	1990	2005	2011	2012	2013	2014	2015
Energy	**5,328.1**	**6,275.3**	**5,721.2**	**5,507.0**	**5,659.1**	**5,704.9**	**5,549.1**
Fossil Fuel Combustion	4,740.3	5,746.9	5,227.1	5,024.6	5,156.5	5,202.3	5,049.8
Natural Gas Systems	231.8	189.8	190.2	191.4	197.7	204.9	204.8
Non-Energy Use of Fuels	117.6	138.9	109.8	106.7	123.6	119.0	125.5
Coal Mining	96.5	64.1	71.2	66.5	64.6	64.8	60.9
Petroleum Systems	59.0	49.9	52.2	50.3	48.2	46.6	43.4
Stationary Combustion	20.4	27.6	28.4	28.0	30.9	31.5	30.1
Mobile Combustion[a]	46.9	38.6	25.1	22.6	20.6	18.6	17.1
Incineration of Waste	8.4	12.9	10.9	10.7	10.7	10.9	11.0
Abandoned Underground Coal Mines	7.2	6.6	6.4	6.2	6.2	6.3	6.4
Industrial Processes and Product Use	**340.4**	**353.4**	**371.0**	**360.9**	**363.7**	**379.8**	**375.9**

Substitution of Ozone Depleting Substances	0.3	99.8	145.4	150.2	154.7	161.3	168.5
Iron and Steel Production & Metallurgical Coke Production	101.5	68.1	61.1	55.5	53.4	58.6	48.9
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9
Petrochemical Production	21.5	27.0	26.4	26.6	26.5	26.6	28.2
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6
Other Process Uses of Carbonates	4.9	6.3	9.3	8.0	10.4	11.8	11.2
Ammonia Production	13.0	9.2	9.3	9.4	10.0	9.6	10.8
Semiconductor Manufacture	3.6	4.7	4.9	4.5	4.1	5.0	5.0
Aluminum Production	28.3	7.6	6.8	6.4	6.2	5.4	4.8
Carbon Dioxide Consumption	1.5	1.4	4.1	4.0	4.2	4.5	4.3
HCFC-22 Production	46.1	20.0	8.8	5.5	4.1	5.0	4.3
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2
Soda Ash Production and Consumption	2.8	3.0	2.7	2.8	2.8	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.9	1.8	1.9	2.0
Titanium Dioxide Production	1.2	1.8	1.7	1.5	1.7	1.7	1.6
Glass Production	1.5	1.9	1.3	1.2	1.3	1.3	1.3
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.0	4.4	4.0	1.4	1.1
Magnesium Production and Processing	5.2	2.7	2.8	1.7	1.5	1.1	1.0
Phosphoric Acid Production	1.5	1.3	1.2	1.1	1.1	1.0	1.0
Zinc Production	0.6	1.0	1.3	1.5	1.4	1.0	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	**495.3**	**526.4**	**541.9**	**525.9**	**516.9**	**514.7**	**522.3**
Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5
Manure Management	51.1	72.9	80.4	83.2	80.8	80.4	84.0
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2
Urea Fertilization	2.4	3.5	4.1	4.3	4.5	4.8	5.0
Liming	4.7	4.3	3.9	6.0	3.9	3.6	3.8
Field Burning of Agricultural Residues	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Waste	**199.3**	**158.2**	**142.6**	**144.4**	**140.4**	**140.2**	**139.4**
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7
Wastewater Treatment	19.1	20.4	20.1	19.9	19.8	19.7	19.7
Composting	0.7	3.5	3.5	3.7	3.9	4.0	4.0
Total Emissions[b]	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**
Land Use, Land-Use Change, and Forestry	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**
Forest Land	(784.3)	(729.8)	(733.8)	(723.6)	(733.5)	(731.8)	(728.7)
Cropland	2.4	(0.7)	4.0	1.3	3.1	4.0	4.7
Grassland	13.8	25.3	9.9	0.8	0.4	0.9	0.4
Wetlands	(3.9)	(5.2)	(3.9)	(4.0)	(4.0)	(4.0)	(4.1)
Settlements	(47.6)	(20.5)	(25.4)	(28.3)	(28.9)	(30.4)	(31.3)
Net Emissions (Sources and Sinks)[c]	**5,543.5**	**6,582.3**	**6,027.6**	**5,784.5**	**5,917.1**	**5,978.3**	**5,827.7**

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF.

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the

transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Total emissions without LULUCF.

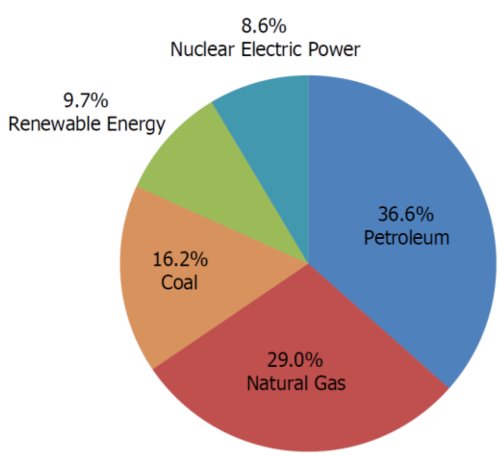
[c] Total emissions with LULUCF.

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

Energy

The Energy chapter contains emissions of all greenhouse gases resulting from stationary and mobile energy activities including fuel combustion and fugitive fuel emissions, and the use of fossil fuels for non-energy purposes. Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions for the period of 1990 through 2015. In 2015, approximately 82 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 18 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure ES-13). Energy-related activities are also responsible for CH_4 and N_2O emissions (42 percent and 12 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy chapter account for a combined 84.2 percent of total U.S. greenhouse gas emissions in 2015.

Figure ES-13: 2015 U.S. Energy Consumption by Energy Source (Percent)



Industrial Processes and Product Use

The Industrial Processes and Product Use (IPPU) chapter includes greenhouse gas emissions occurring from industrial processes and from the use of greenhouse gases in products.

Greenhouse gas emissions are produced as the by-products of many non-energy-related industrial activities. For example, industrial processes can chemically transform raw materials, which often release waste gases such as CO_2, CH_4, and N_2O. These processes include iron and steel production and metallurgical coke production, cement production, ammonia production, urea consumption, lime production, other process uses of carbonates (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and consumption, titanium dioxide production, phosphoric acid production, ferroalloy production, CO_2 consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, zinc production, and N_2O from product uses. Industrial processes also release HFCs, PFCs, SF_6, and NF_3 and other fluorinated compounds. In addition to the use of HFCs and some PFCs as ODS substitutes, HFCs, PFCs, SF_6, NF_3, and other fluorinated compounds are employed and emitted by a number of other industrial sources in the United States. These industries include aluminum production, HCFC-22 production, semiconductor manufacture, electric power transmission and distribution, and magnesium metal production and processing. Overall, emission sources in the Industrial Process and Product Use chapter account for 5.7 percent of U.S. greenhouse gas emissions in 2015.

Agriculture

The Agriculture chapter contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy chapter, and some agricultural CO_2 fluxes, which are addressed in the Land Use, Land-Use Change, and Forestry chapter). Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including the following source categories: enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, liming, urea fertilization, and field burning of agricultural residues. In 2015, agricultural activities were responsible for emissions of 522.3 MMT CO2 Eq., or 7.9 percent of total U.S. greenhouse gas emissions. Methane, nitrous oxide and carbon dioxide were the primary greenhouse gases emitted by agricultural activities. Methane emissions from enteric fermentation and manure management represented approximately 25.4 percent and 10.1 percent of total CH4 emissions from anthropogenic activities, respectively, in 2015. Agricultural soil management activities, such as application of synthetic and organic fertilizers, deposition of livestock manure, and growing N-fixing plants, were the largest source of U.S. N2O emissions in 2015, accounting for 75.1 percent. Carbon dioxide emissions from the application of crushed limestone and dolomite (i.e., soil liming) and urea fertilization represented 0.2 percent of total CO2 emissions from anthropogenic activities. Figure 2-11 and Table 2-7 illustrate agricultural greenhouse gas emissions by source.

Land Use, Land-Use Change, and Forestry

The Land Use, Land-Use Change, and Forestry chapter contains emissions of CH_4 and N_2O, and emissions and removals of CO_2 from managed lands in the United States. Overall, managed land is a net sink for CO_2 (C sequestration) in the United States. The primary drivers of fluxes on managed lands include, for example, forest management practices, tree planting in urban areas, the management of agricultural soils, landfilling of yard trimmings and food scraps, and activities that cause changes in C stocks in coastal wetlands. The main drivers for forest C sequestration include forest growth and increasing forest area, as well as a net accumulation of C stocks in harvested wood pools. The net sequestration in *Settlements Remaining Settlements*, which occurs predominantly from urban forests and landfilled yard trimmings and food scraps, is a result of net tree growth and increased urban forest size, as well as long-term accumulation of yard trimmings and food scraps carbon in landfills.

The LULUCF sector in 2015 resulted in a net increase in C stocks (i.e., net CO_2 removals) of 778.7 MMT CO_2 Eq. (Table ES-5).[21] This represents an offset of 11.8 percent of total (i.e., gross) greenhouse gas emissions in 2015. Emissions of CH_4 and N_2O from LULUCF activities in 2015 are 19.7 MMT CO_2 Eq. and represent 0.3 percent of total greenhouse gas emissions.[22] Between 1990 and 2015, total C sequestration in the LULUCF sector decreased by 6.2 percent, primarily due to a decrease in the rate of net C accumulation in forests and an increase in CO_2 emissions from *Land Converted to Settlements*.

Carbon dioxide removals from C stock changes are presented in Table ES-5 along with CH_4 and N_2O emissions for LULUCF source categories. Forest fires were the largest source of CH_4 emissions from LULUCF in 2015, totaling 7.3 MMT CO_2 Eq. (292 kt of CH_4). *Coastal Wetlands Remaining Coastal Wetlands* resulted in CH_4 emissions of 3.6 MMT CO_2 Eq. (143 kt of CH_4). Grassland fires resulted in CH_4 emissions of 0.4 MMT CO_2 Eq. (16 kt of CH_4). *Peatlands Remaining Peatlands*, *Land Converted to Wetlands*, and *Drained Organic Soils* resulted in CH_4 emissions of less than 0.05 MMT CO_2 Eq each.

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[21] 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.*

[22] 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.

Forest fires were also the largest source of N_2O emissions from LULUCF in 2015, totaling 4.8 MMT CO_2 Eq. (16 kt of N_2O). Nitrous oxide emissions from fertilizer application to settlement soils in 2015 totaled to 2.5 MMT CO_2 Eq. (8 kt of N_2O). This represents an increase of 76.6 percent since 1990. Additionally, the application of synthetic fertilizers to forest soils in 2015 resulted in N_2O emissions of 0.5 MMT CO_2 Eq. (2 kt of N_2O). Nitrous oxide emissions from fertilizer application to forest soils have increased by 455 percent since 1990, but still account for a relatively small portion of overall emissions. Grassland fires resulted in N_2O emissions of 0.4 MMT CO_2 Eq. (1 kt of N_2O). *Coastal Wetlands Remaining Coastal Wetlands* and *Drained Organic Soils* resulted in N_2O emissions of 0.1 MMT CO_2 Eq. each (less than 0.5 kt of N_2O), and *Peatlands Remaining Peatlands* resulted in N_2O emissions of less than 0.05 MMT CO_2 Eq.

Table ES-5: U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry (MMT CO_2 Eq.)

Gas/Land-Use Category	1990	2005	2011	2012	2013	2014	2015
Carbon Stock Change[a]	**(830.2)**	**(754.0)**	**(769.1)**	**(779.8)**	**(782.2)**	**(781.1)**	**(778.7)**
Forest Land Remaining Forest Land	(697.7)	(664.6)	(670.0)	(666.9)	(670.8)	(669.3)	(666.2)
Land Converted to Forest Land	(92.0)	(81.4)	(75.8)	(75.2)	(75.2)	(75.2)	(75.2)
Cropland Remaining Cropland	(40.9)	(26.5)	(19.1)	(21.4)	(19.6)	(18.7)	(18.0)
Land Converted to Cropland	43.3	25.9	23.2	22.7	22.7	22.7	22.7
Grassland Remaining Grassland	(4.2)	5.5	(12.5)	(20.8)	(20.5)	(20.4)	(20.9)
Land Converted to Grassland	17.9	19.2	20.7	20.4	20.5	20.5	20.5
Wetlands Remaining Wetlands	(7.6)	(8.9)	(7.6)	(7.7)	(7.8)	(7.8)	(7.8)
Land Converted to Wetlands	+	+	+	+	+	+	+
Settlements Remaining Settlements	(86.2)	(91.4)	(98.7)	(99.2)	(99.8)	(101.2)	(102.1)
Land Converted to Settlements	37.2	68.4	70.7	68.3	68.3	68.3	68.3
CH_4	**6.7**	**13.3**	**11.2**	**14.9**	**11.0**	**11.3**	**11.3**
Forest Land Remaining Forest Land: Forest Fires	3.2	9.4	6.8	10.8	7.2	7.3	7.3
Wetlands Remaining Wetlands: Coastal Wetlands Remaining Coastal Wetlands	3.4	3.5	3.5	3.5	3.6	3.6	3.6
Grassland Remaining Grassland: Grass Fires	0.1	0.3	0.8	0.6	0.2	0.4	0.4
Forest Land Remaining Forest Land: Drained Organic Soils	+	+	+	+	+	+	+
Land Converted to Wetlands: Land Converted to Coastal Wetlands	+	+	+	+	+	+	+
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
N_2O	**3.9**	**9.7**	**8.7**	**11.1**	**8.2**	**8.4**	**8.4**
Forest Land Remaining Forest Land: Forest Fires	2.1	6.2	4.5	7.1	4.7	4.8	4.8
Settlements Remaining Settlements: Settlement Soils[b]	1.4	2.5	2.6	2.7	2.6	2.5	2.5
Forest Land Remaining Forest Land: Forest Soils[c]	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Grassland Remaining Grassland: Grass Fires	0.1	0.3	0.9	0.6	0.2	0.4	0.4
Wetlands Remaining Wetlands: Coastal Wetlands Remaining Coastal Wetlands	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Forest Land Remaining Forest Land: Drained Organic Soils	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
LULUCF Emissions[d]	**10.6**	**23.0**	**19.9**	**26.1**	**19.2**	**19.7**	**19.7**
LULUCF Carbon Stock Change[a]	**(830.2)**	**(754.0)**	**(769.1)**	**(779.8)**	**(782.2)**	**(781.1)**	**(778.7)**
LULUCF Sector Net Total[e]	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**

+ Absolute value does not exceed 0.05 MMT CO_2 Eq.

[a] 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.*

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

Waste

The Waste chapter contains emissions from waste management activities (except incineration of waste, which is addressed in the Energy chapter). Landfills were the largest source of anthropogenic greenhouse gas emissions in the Waste chapter, accounting for 83.0 percent of this chapter's emissions, and 17.6 percent of total U.S. CH_4 emissions.[23] Additionally, wastewater treatment accounts for 14.2 percent of Waste emissions, 2.3 percent of U.S. CH_4 emissions, and 1.5 percent of U.S. N_2O emissions. Emissions of CH_4 and N_2O from composting are also accounted for in this chapter, generating emissions of 2.1 MMT CO_2 Eq. and 1.9 MMT CO_2 Eq., respectively. Overall, emission sources accounted for in the Waste chapter generated 2.1 percent of total U.S. greenhouse gas emissions in 2015.

ES.4 Other Information

Emissions by Economic Sector

Throughout the Inventory of U.S. Greenhouse Gas Emissions and Sinks report, emission estimates are grouped into five sectors (i.e., chapters) defined by the IPCC: Energy; Industrial Processes and Product Use; Agriculture; LULUCF; and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines and to promote comparability across countries, it is also useful to characterize emissions according to commonly used economic sector categories: residential, commercial, industry, transportation, electricity generation, agriculture, and U.S. Territories.

Table ES-6 summarizes emissions from each of these economic sectors, and Figure ES-14 shows the trend in emissions by sector from 1990 to 2015.

[23] Landfills also store carbon, due to incomplete degradation of organic materials such as harvest wood products, yard trimmings, and food scraps, as described in the Land-Use, Land-Use Change, and Forestry chapter of the Inventory report.

Figure ES-14: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq.)

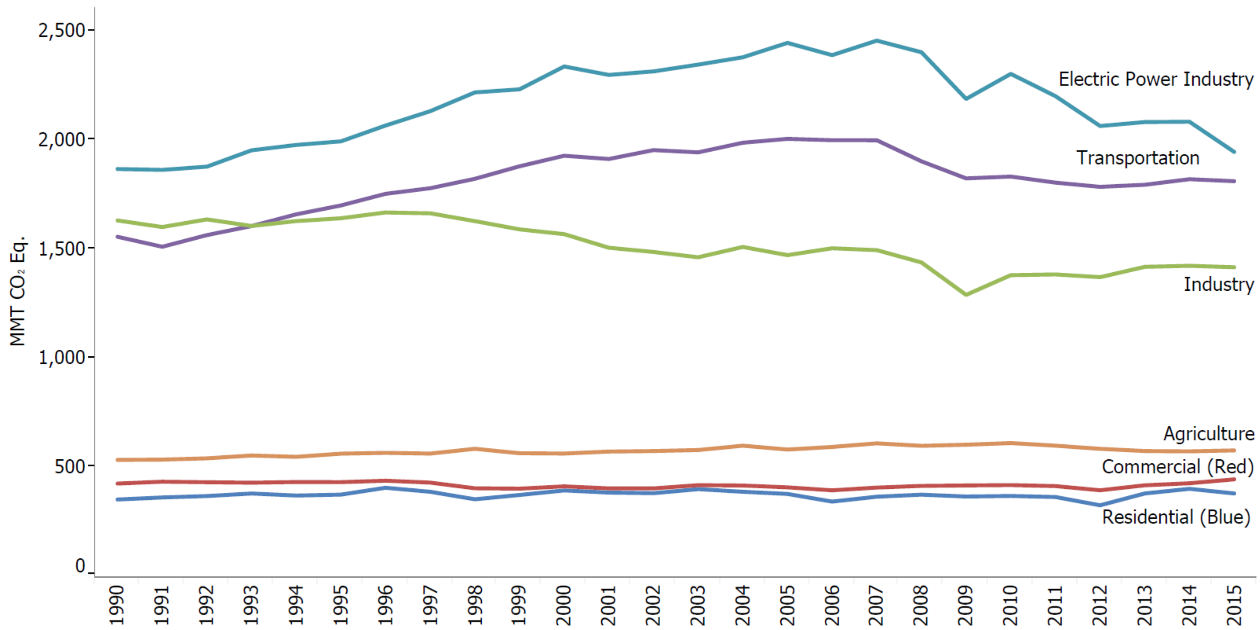


Table ES-6: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq.)

Economic Sectors	1990	2005	2011	2012	2013	2014	2015
Electric Power Industry	1,862.5	2,441.6	2,197.3	2,059.9	2,078.2	2,079.7	1,941.4
Transportation[a]	1,551.2	2,001.0	1,800.0	1,780.7	1,790.2	1,815.8	1,806.6
Industry[a]	1,626.3	1,467.1	1,378.6	1,365.9	1,413.4	1,418.0	1,411.6
Agriculture	526.7	574.3	592.0	577.6	567.5	566.1	570.3
Commercial[a]	418.1	400.7	406.5	387.3	410.1	419.5	437.4
Residential	344.9	370.4	356.3	318.4	372.6	393.9	372.7
U.S. Territories	33.3	58.1	46.0	48.5	48.1	46.6	46.6
Total Emissions	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**
LULUCF Sector Net Total[b]	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**
Net Emissions (Sources and Sinks)	**5,543.5**	**6,582.3**	**6,027.6**	**5,784.5**	**5,917.1**	**5,978.3**	**5,827.7**

Notes: Total emissions presented without LULUCF. Total net emissions presented with LULUCF.

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] 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 negative values or sequestration.

Using this categorization, emissions from electricity generation accounted for the largest portion (29 percent) of total U.S. greenhouse gas emissions in 2015. Transportation activities, in aggregate, accounted for the second largest portion (27 percent), while emissions from industry accounted for the third largest portion (21 percent) of total U.S. greenhouse gas emissions in 2015. Emissions from industry have in general declined over the past decade, due to a number of factors, including structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and energy efficiency improvements. The remaining 22 percent of U.S. greenhouse gas emissions were contributed by, in order of magnitude, the agriculture, commercial, and residential sectors, plus emissions from U.S. Territories. Activities related to agriculture accounted for 9 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation. The commercial and residential sectors accounted for 7 percent and 6 percent of emissions, respectively, and U.S. Territories accounted for 1 percent of emissions; emissions from these sectors primarily consisted of CO_2 emissions from fossil fuel combustion. CO_2 was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, landfilling of yard trimmings, and changes in C stocks in coastal wetlands.

Electricity is ultimately consumed in the economic sectors described above. Table ES-7 presents greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). To distribute electricity emissions among end-use sectors, emissions from the source categories assigned to electricity generation were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity.[24] These source categories include CO_2 from fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO_2 and N_2O from incineration of waste, CH_4 and N_2O from stationary sources, and SF_6 from electrical transmission and distribution systems.

When emissions from electricity are distributed among these sectors, industrial activities and transportation account for the largest shares of U.S. greenhouse gas emissions (29 percent and 27 percent, respectively) in 2015. The residential and commercial sectors contributed the next largest shares of total U.S. greenhouse gas emissions in 2015. Emissions from these sectors increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption (e.g., lighting, appliances). In all sectors except agriculture, CO_2 accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

Figure ES-15 shows the trend in these emissions by sector from 1990 to 2015.

Table ES-7: U.S. Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed (MMT CO_2 Eq.)

Implied Sectors	**1990**	**2005**	**2011**	**2012**	**2013**	**2014**	**2015**
Industry[a]	2,293.9	2,178.1	1,973.6	1,926.7	1,977.4	1,978.7	1,931.1
Transportation[a]	1,554.4	2,005.9	1,804.3	1,784.7	1,794.3	1,820.0	1,810.4
Commercial[a]	968.4	1,217.6	1,158.1	1,100.6	1,128.5	1,139.9	1,114.8
Residential	951.5	1,241.3	1,161.5	1,057.2	1,122.0	1,143.7	1,071.6
Agriculture	561.5	612.4	633.1	620.6	609.9	610.8	612.0
U.S. Territories	33.3	58.1	46.0	48.5	48.1	46.6	46.6
Total Emissions	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**
LULUCF Sector Net Total[b]	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**
Net Emissions (Sources and Sinks)	**5,543.5**	**6,582.3**	**6,027.6**	**5,784.5**	**5,917.1**	**5,978.3**	**5,827.7**

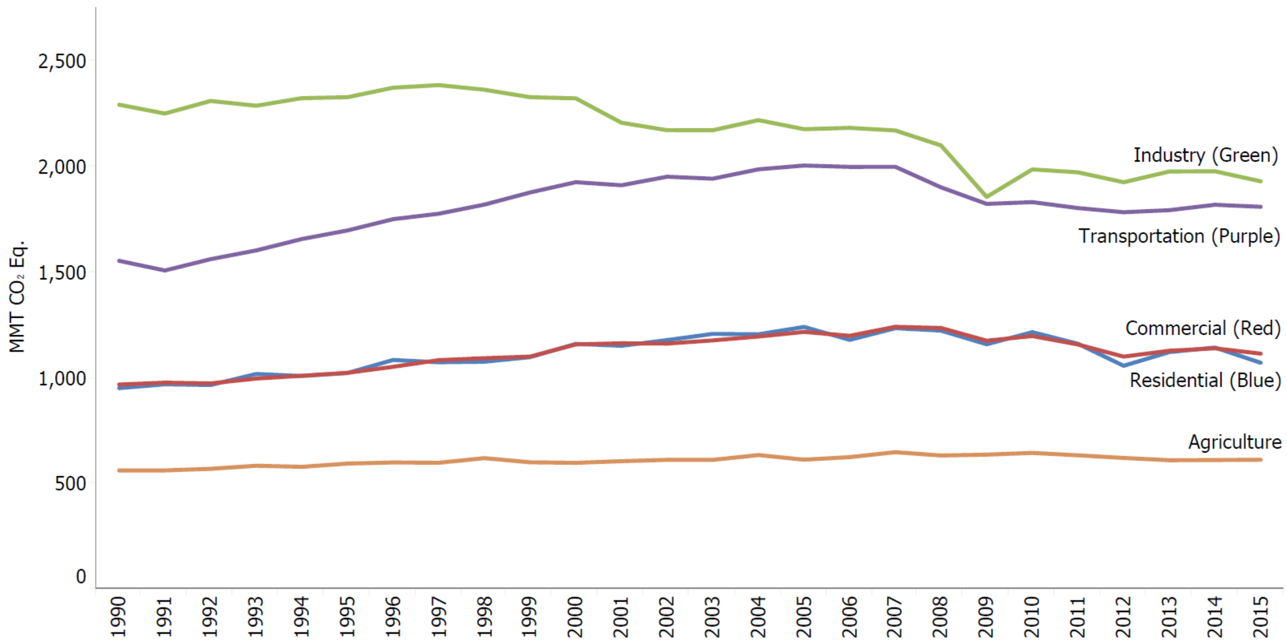
[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] 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: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

[24] Emissions were not distributed to U.S. Territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

Figure ES-15: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed to Economic Sectors (MMT CO_2 Eq.)



Box ES-4: Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and non-utilities combined—was the largest source of U.S. greenhouse gas emissions in 2015; (4) emissions per unit of total gross domestic product as a measure of national economic activity; and (5) emissions per capita.

Table ES-8 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. These values represent the relative change in each statistic since 1990. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.2 percent since 1990. Since 1990, this rate is slightly slower than that for total energy and for fossil fuel consumption, and much slower than that for electricity consumption, overall gross domestic product (GDP) and national population (see Figure ES-16). These trends vary relative to 2005, when greenhouse gas emissions, total energy and fossil fuel consumption began to peak. Greenhouse gas emissions in the United States have decreased at an average annual rate of 1.0 percent since 2005. Total energy and fossil fuel consumption have also decreased at slower rates than emissions since 2005, while electricity consumption, GDP, and national population continued to increase.

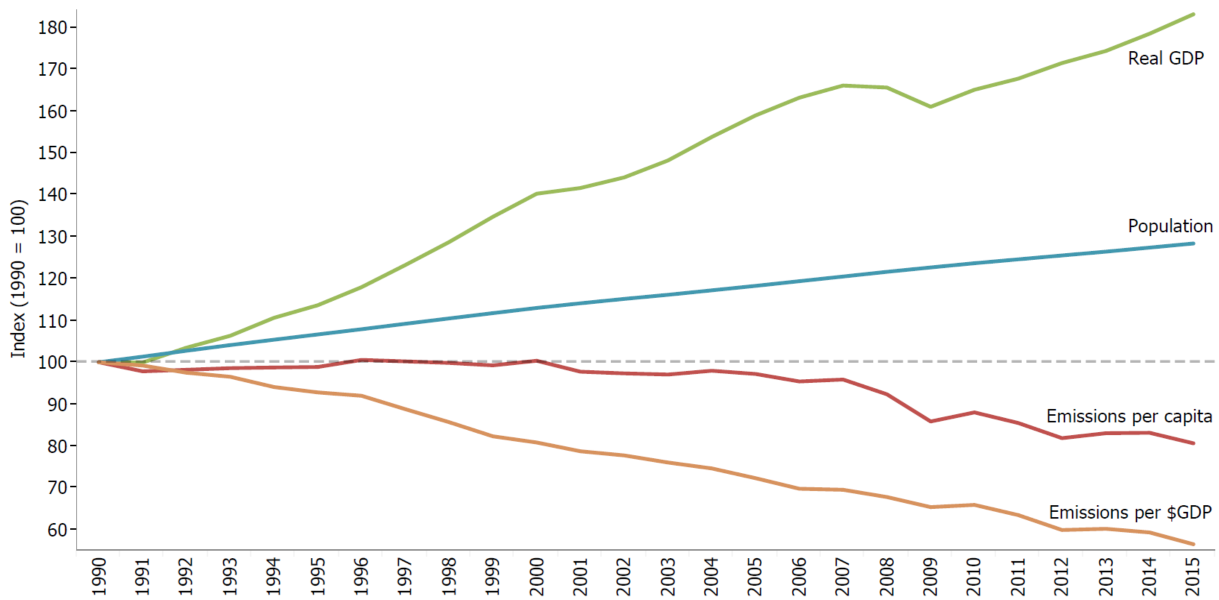
Table ES-8: Recent Trends in Various U.S. Data (Index 1990 = 100)

Variable	1990		2005		2011	2012	2013	2014	2015	Avg. Annual Change since 1990	Avg. Annual Change since 2005
Greenhouse Gas Emissions[a]	100		115		107	103	105	106	104	0.2%	-1.0%
Energy Consumption[b]	100		118		115	112	115	117	115	0.6%	-0.2%
Fossil Fuel Consumption[b]	100		119		110	107	110	111	110	0.4%	-0.7%
Electricity Consumption[b]	100		134		137	135	136	138	137	1.3%	0.3%
GDP[c]	100		159		168	171	174	178	183	2.5%	1.4%
Population[d]	100		118		125	126	126	127	128	1.0%	0.8%

[a] GWP-weighted values

[b] Energy content-weighted values (EIA 2016)
[c] Gross Domestic Product in chained 2009 dollars (BEA 2017)
[d] U.S. Census Bureau (2016)

Figure ES-16: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product (GDP)



Source: BEA (2017), U.S. Census Bureau (2016), and emission estimates in this report.

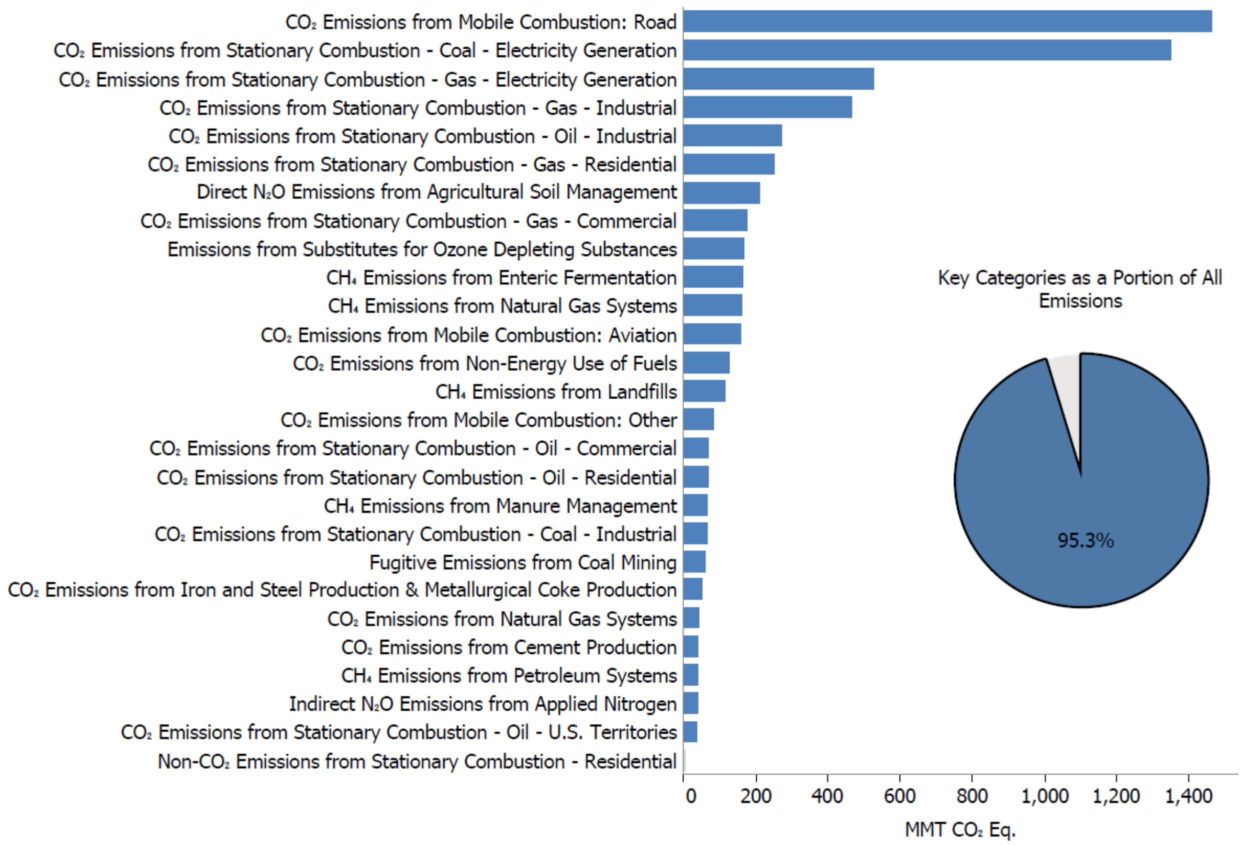
Key Categories

The *2006 IPCC Guidelines* (IPCC 2006) defines a key category as a "[category] that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals."[25] By definition, key categories are sources or sinks that have the greatest contribution to the absolute overall level of national emissions in any of the years covered by the time series. In addition, when an entire time series of emission estimates is prepared, a thorough investigation of key categories must also account for the influence of trends of individual source and sink categories. Finally, a qualitative evaluation of key categories should be performed, in order to capture any key categories that were not identified in either of the quantitative analyses.

Figure ES-17 presents 2015 emission estimates for the key categories as defined by a level analysis (i.e., the absolute value of the contribution of each source or sink category to the total inventory level). The UNFCCC reporting guidelines request that key category analyses be reported at an appropriate level of disaggregation, which may lead to source and sink category names which differ from those used elsewhere in the Inventory report. For more information regarding key categories, see Section 1.5 – Key Categories and Annex 1.

[25] See Chapter 4 "Methodological Choice and Identification of Key Categories" in IPCC (2006). See <http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html>.

Figure ES-17: 2015 Key Categories (MMT CO_2 Eq.)



Note: For a complete discussion of the key category analysis, see Annex 1. Blue bars indicate either an Approach 1, or Approach 1 *and* Approach 2 level assessment key category. Gray bars indicate solely an Approach 2 level assessment key category.

Quality Assurance and Quality Control (QA/QC)

The United States seeks to continually improve the quality, transparency, and credibility of the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. To assist in these efforts, the United States implemented a systematic approach to QA/QC. The procedures followed for the Inventory have been formalized in accordance with the *Quality Assurance/Quality Control and Uncertainty Management Plan* (QA/QC Management Plan) for the Inventory, and the UNFCCC reporting guidelines. The QA process includes expert and public reviews for both the Inventory estimates and the Inventory report.

Uncertainty Analysis of Emission Estimates

Uncertainty estimates are an essential element of a complete inventory of greenhouse gas emissions and removals, because they help to prioritize future work and improve overall quality. Some of the current estimates, such as those for CO_2 emissions from energy-related activities, are considered to have low uncertainties. This is because the amount of CO_2 emitted from energy-related activities is directly related to the amount of fuel consumed, the fraction of the fuel that is oxidized, and the carbon content of the fuel and, for the United States, the uncertainties associated with estimating those factors is believed to be relatively small. For some other categories of emissions, however, a lack of data or an incomplete understanding of how emissions are generated increases the uncertainty or systematic error associated with the estimates presented. Recognizing the benefit of conducting an uncertainty analysis, the UNFCCC reporting guidelines follow the recommendations of the *2006 IPCC Guidelines* (IPCC 2006), Volume 1, Chapter 3 and require that countries provide single estimates of uncertainty for source and sink categories.

In addition to quantitative uncertainty assessments provided in accordance with UNFCCC reporting guidelines, a qualitative discussion of uncertainty is presented for all source and sink categories. Within the discussion of each emission source, specific factors affecting the uncertainty surrounding the estimates are discussed.

Box ES-5: Recalculations of Inventory Estimates

Each year, emission and sink estimates are recalculated and revised for all years in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, as attempts are made to improve both the analyses themselves, through the use of better methods or data, and the 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; new inventory methods become available; and for correction of errors." In general, recalculations are made to the U.S. greenhouse gas emission estimates either to incorporate new methodologies or, most commonly, to update recent historical data.

In each Inventory report, the results of all methodology changes and historical data updates are presented in the Recalculations and Improvements chapter; detailed descriptions of each recalculation are contained within each source's description contained in the report, if applicable. In general, when methodological changes have been implemented, the entire time series (in the case of the most recent Inventory report, 1990 through 2014) has been recalculated to reflect the change, per the *2006 IPCC Guidelines* (IPCC 2006). Changes in historical data are generally the result of changes in statistical data supplied by other agencies. References for the data are provided for additional information.

2. Trends in Greenhouse Gas Emissions

2.1 Recent Trends in U.S. Greenhouse Gas Emissions and Sinks

In 2015, total gross U.S. greenhouse gas emissions were 6,586.7 MMT, or million metric tons, carbon dioxide (CO_2) Eq. Total U.S. emissions have increased by 3.5 percent from 1990 to 2015, and emissions decreased from 2014 to 2015 by 2.3 percent (153.0 MMT CO_2 Eq.). The decrease in total greenhouse gas emissions between 2014 and 2015 was driven in large part by a decrease in CO_2 emissions from fossil fuel combustion. The decrease in CO_2 emissions from fossil fuel combustion was a result of multiple factors, including: (1) substitution from coal to natural gas consumption in the electric power sector; (2) warmer winter conditions in 2015 resulting in a decreased demand for heating fuel in the residential and commercial sectors; and (3) a slight decrease in electricity demand. Since 1990, U.S. emissions have increased at an average annual rate of 0.2 percent. Figure 2-1 through Figure 2-3 illustrate the overall trend in total U.S. emissions by gas, annual changes, and absolute changes since 1990. Overall, net emissions in 2015 were 11.5 percent below 2005 levels as shown in Table 2-1.

Figure 2-1: Gross U.S. Greenhouse Gas Emissions by Gas (MMT CO_2 Eq.)

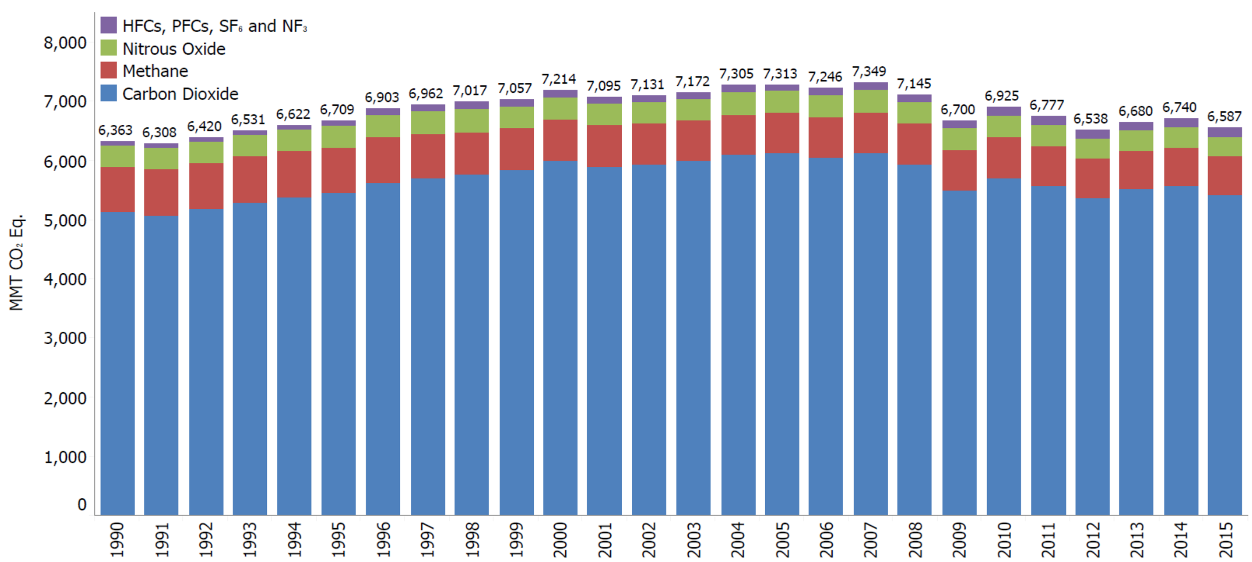


Figure 2-2: Annual Percent Change in Gross U.S. Greenhouse Gas Emissions Relative to the Previous Year

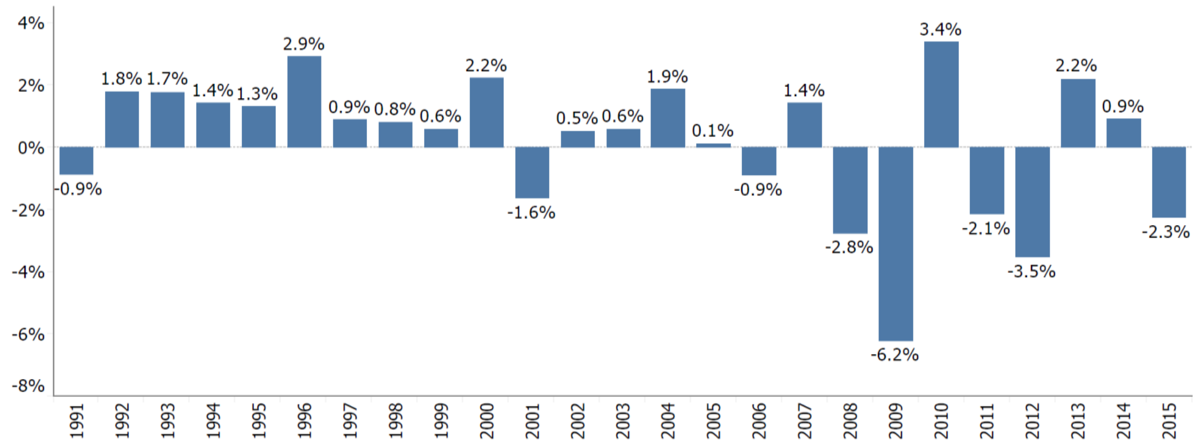
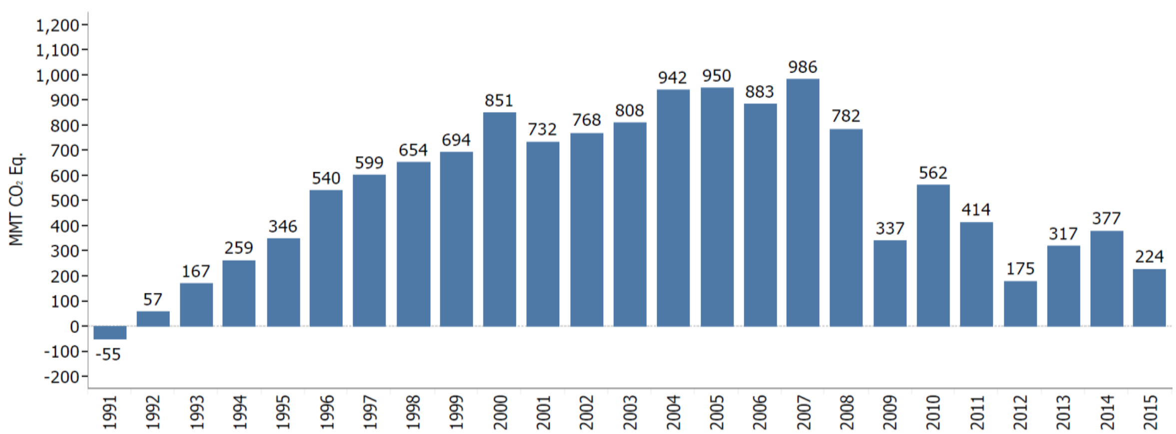


Figure 2-3: Cumulative Change in Annual Gross U.S. Greenhouse Gas Emissions Relative to 1990 (1990=0, MMT CO_2 Eq.)



Overall, from 1990 to 2015, total emissions of CO_2 increased by 288.4 MMT CO_2 Eq. (5.6 percent), while total emissions of methane (CH_4) decreased by 125.1 MMT CO_2 Eq. (16.0 percent), and total emissions of nitrous oxide (N_2O) decreased by 24.7 MMT CO_2 Eq. (6.9 percent). During the same period, aggregate weighted emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) rose by 85.0 MMT CO_2 Eq. (85.3 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, SF_6, and NF_3 are significant because many of them have extremely high global warming potentials (GWPs), and, in the cases of PFCs, SF_6, and NF_3, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon (C) sequestration in managed forests, trees in urban areas, agricultural soils, landfilled yard trimmings, and coastal wetlands. These were estimated to offset 11.8 percent of total emissions in 2015.

As the largest contributor to U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 77 percent of GWP-weighted emissions for the entire time series since 1990. Emissions from this source category grew by 6.5 percent (309.4 MMT CO_2 Eq.) from 1990 to 2015 and were responsible for most of the increase in national emissions during this period. In addition, CO_2 emissions from fossil fuel combustion decreased from 2005 levels by 697.2 MMT CO_2 Eq., a decrease of approximately 12.1 percent between 2005 and 2015. From 2014 to 2015, these emissions decreased by 2.9 percent (152.5 MMT CO_2 Eq.). Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends.

Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations and market trends, technological changes, energy fuel choices, and seasonal temperatures. On an annual basis, the overall consumption and mix of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, overall energy prices, the relative price of different fuels, weather, and the availability of non-fossil alternatives. For example, coal consumption for electricity generation is influenced by a number of factors including the relative price of coal and alternative sources, the ability to switch fuels, and longer terms trends in coal markets. Likewise, warmer winters will lead to a decrease in heating degree days and result in a decreased demand for heating fuel and electricity for heat in the residential and commercial sector, which leads to a decrease in emissions from reduced fuel use.

Energy-related CO_2 emissions also depend on the type of fuel or energy consumed and its C intensity. Producing a unit of heat or electricity using natural gas instead of coal, for example, can reduce the CO_2 emissions because of the lower C content of natural gas (see Table A-39 in Annex 2.1 for more detail on the C Content Coefficient of different fossil fuels).

A brief discussion of the year to year variability in fuel combustion emissions is provided below, beginning with 2011.

Recent trends in CO_2 emissions from fossil fuel combustion show a 3.9 percent decrease from 2011 to 2012, then a 2.6 percent and a 0.9 percent increase from 2012 to 2013 and 2013 to 2014, respectively, and a 2.9 percent decrease from 2014 to 2015. Total electricity generation remained relatively flat over that time period but emission trends generally mirror the trends in the amount of coal used to generate electricity. The consumption of coal used to generate electricity decreased by roughly 12 percent from 2011 to 2012, increased by 4 percent from 2012 to 2013, stayed relatively flat from 2013 to 2014, and decreased by 14 percent from 2014 to 2015. The overall CO_2 emission trends from fossil fuel combustion also follow closely changes in heating degree days over that time period. Heating degree days decreased by 13 percent from 2011 to 2012, increased by 18 percent from 2012 to 2013, increased by 2 percent from 2013 to 2014, and decreased by 10 percent from 2014 to 2015. The overall CO_2 emission trends from fossil fuel combustion also generally follow changes in overall petroleum use and emissions. Carbon dioxide emissions from petroleum decreased by 2.0 percent from 2011 to 2012, increased by 1.6 percent from 2012 to 2013, increased by 0.8 percent from 2013 to 2014, and increased by 1.7 percent from 2014 to 2015. The increase in petroleum CO_2 emissions from 2014 to 2015 somewhat offset emission reductions from decreased coal use in the electricity sector from 2014 to 2015.

Table 2-1 summarizes emissions and sinks from all U.S. anthropogenic sources in weighted units of MMT CO_2 Eq., while unweighted gas emissions and sinks in kilotons (kt) are provided in Table 2-2.

Table 2-1: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**5,123.0**	**6,131.8**	**5,569.5**	**5,362.1**	**5,514.0**	**5,565.5**	**5,411.4**
Fossil Fuel Combustion	4,740.3	5,746.9	5,227.1	5,024.6	5,156.5	5,202.3	5,049.8
Electricity Generation	*1,820.8*	*2,400.9*	*2,157.7*	*2,022.2*	*2,038.1*	*2,038.0*	*1,900.7*
Transportation[a]	*1,493.8*	*1,887.0*	*1,707.6*	*1,696.8*	*1,713.0*	*1,742.8*	*1,736.4*
Industrial[a]	*842.5*	*828.0*	*775.0*	*782.9*	*812.2*	*806.1*	*805.5*
Residential	*338.3*	*357.8*	*325.5*	*282.5*	*329.7*	*345.4*	*319.6*
Commercial[a]	*217.4*	*223.5*	*220.4*	*196.7*	*221.0*	*228.7*	*246.2*
U.S. Territories	*27.6*	*49.7*	*40.9*	*43.5*	*42.5*	*41.4*	*41.4*
Non-Energy Use of Fuels	117.6	138.9	109.8	106.7	123.6	119.0	125.5
Iron and Steel Production & Metallurgical Coke Production	101.5	68.0	61.1	55.4	53.3	58.6	48.9
Natural Gas Systems	37.7	30.1	35.7	35.2	38.5	42.4	42.4
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9
Petrochemical Production	21.3	27.0	26.3	26.5	26.4	26.5	28.1
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3
Other Process Uses of Carbonates	4.9	6.3	9.3	8.0	10.4	11.8	11.2

Ammonia Production	13.0		9.2		9.3	9.4	10.0	9.6	10.8
Incineration of Waste	8.0		12.5		10.6	10.4	10.4	10.6	10.7
Urea Fertilization	2.4		3.5		4.1	4.3	4.5	4.8	5.0
Carbon Dioxide Consumption	1.5		1.4		4.1	4.0	4.2	4.5	4.3
Liming	4.7		4.3		3.9	6.0	3.9	3.6	3.8
Petroleum Systems	3.6		3.9		4.2	3.9	3.7	3.6	3.6
Soda Ash Production and Consumption	2.8		3.0		2.7	2.8	2.8	2.8	2.8
Aluminum Production	6.8		4.1		3.3	3.4	3.3	2.8	2.8
Ferroalloy Production	2.2		1.4		1.7	1.9	1.8	1.9	2.0
Titanium Dioxide Production	1.2		1.8		1.7	1.5	1.7	1.7	1.6
Glass Production	1.5		1.9		1.3	1.2	1.3	1.3	1.3
Urea Consumption for Non-Agricultural Purposes	3.8		3.7		4.0	4.4	4.0	1.4	1.1
Phosphoric Acid Production	1.5		1.3		1.2	1.1	1.1	1.0	1.0
Zinc Production	0.6		1.0		1.3	1.5	1.4	1.0	0.9
Lead Production	0.5		0.6		0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4		0.2		0.2	0.2	0.2	0.2	0.2
Magnesium Production and Processing	+		+		+	+	+	+	+
Wood Biomass, Ethanol, and Biodiesel Consumption[b]	*219.4*		*230.7*		*276.4*	*276.2*	*299.8*	*307.1*	*291.7*
International Bunker Fuels[c]	*103.5*		*113.1*		*111.7*	*105.8*	*99.8*	*103.2*	*110.8*
CH_4	**780.8**		**680.9**		**672.1**	**666.1**	**658.8**	**659.1**	**655.7**
Enteric Fermentation	164.2		168.9		168.9	166.7	165.5	164.2	166.5
Natural Gas Systems	194.1		159.7		154.5	156.2	159.2	162.5	162.4
Landfills	179.6		134.3		119.0	120.8	116.7	116.6	115.7
Manure Management	37.2		56.3		63.0	65.6	63.3	62.9	66.3
Coal Mining	96.5		64.1		71.2	66.5	64.6	64.8	60.9
Petroleum Systems	55.5		46.0		48.0	46.4	44.5	43.0	39.9
Wastewater Treatment	15.7		16.0		15.3	15.1	14.9	14.8	14.8
Rice Cultivation	16.0		16.7		14.1	11.3	11.3	11.4	11.2
Stationary Combustion	8.5		7.4		7.1	6.6	8.0	8.1	7.0
Abandoned Underground Coal Mines	7.2		6.6		6.4	6.2	6.2	6.3	6.4
Composting	0.4		1.9		1.9	1.9	2.0	2.1	2.1
Mobile Combustion[a]	5.6		2.8		2.3	2.2	2.1	2.1	2.0
Field Burning of Agricultural Residues	0.2		0.2		0.3	0.3	0.3	0.3	0.3
Petrochemical Production	0.2		0.1		+	0.1	0.1	0.1	0.2
Ferroalloy Production	+		+		+	+	+	+	+
Silicon Carbide Production and Consumption	+		+		+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+		+		+	+	+	+	+
Incineration of Waste	+		+		+	+	+	+	+
International Bunker Fuels[c]	*0.2*		*0.1*		*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**359.5**		**361.6**		**364.0**	**340.7**	**335.5**	**335.5**	**334.8**
Agricultural Soil Management	256.6		259.8		270.1	254.1	250.5	250.0	251.3
Stationary Combustion	11.9		20.2		21.3	21.4	22.9	23.4	23.1
Manure Management	14.0		16.5		17.4	17.5	17.5	17.5	17.7
Mobile Combustion[a]	41.2		35.7		22.8	20.4	18.5	16.6	15.1
Nitric Acid Production	12.1		11.3		10.9	10.5	10.7	10.9	11.6
Wastewater Treatment	3.4		4.4		4.8	4.8	4.9	4.9	5.0
Adipic Acid Production	15.2		7.1		10.2	5.5	3.9	5.4	4.3
N_2O from Product Uses	4.2		4.2		4.2	4.2	4.2	4.2	4.2
Composting	0.3		1.7		1.7	1.7	1.8	1.9	1.9
Incineration of Waste	0.5		0.4		0.3	0.3	0.3	0.3	0.3

Semiconductor Manufacture	+	0.1	0.2	0.2	0.2	0.2	0.2
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
International Bunker Fuels[c]	*0.9*	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.9*
HFCs	**46.6**	**120.0**	**154.3**	**155.9**	**159.0**	**166.7**	**173.2**
Substitution of Ozone Depleting Substances[d]	0.3	99.7	145.3	150.2	154.6	161.3	168.5
HCFC-22 Production	46.1	20.0	8.8	5.5	4.1	5.0	4.3
Semiconductor Manufacture	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Magnesium Production and Processing	0.0	0.0	+	+	0.1	0.1	0.1
PFCs	**24.3**	**6.7**	**6.9**	**6.0**	**5.8**	**5.8**	**5.2**
Semiconductor Manufacture	2.8	3.2	3.4	3.0	2.8	3.2	3.2
Aluminum Production	21.5	3.4	3.5	2.9	3.0	2.5	2.0
Substitution of Ozone Depleting Substances	0.0	+	+	+	+	+	+
SF_6	**28.8**	**11.7**	**9.2**	**6.8**	**6.4**	**6.6**	**5.8**
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2
Magnesium Production and Processing	5.2	2.7	2.8	1.6	1.5	1.0	0.9
Semiconductor Manufacture	0.5	0.7	0.4	0.4	0.4	0.7	0.7
NF_3	**+**	**0.5**	**0.7**	**0.6**	**0.6**	**0.5**	**0.6**
Semiconductor Manufacture	+	0.5	0.7	0.6	0.6	0.5	0.6
Total Emissions	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**
LULUCF Emissions[e]	**10.6**	**23.0**	**19.9**	**26.1**	**19.2**	**19.7**	**19.7**
LULUCF Carbon Stock Change[f]	**(830.2)**	**(754.0)**	**(769.1)**	**(779.8)**	**(782.2)**	**(781.1)**	**(778.7)**
LULUCF Sector Net Total[g]	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**
Net Emissions (Sources and Sinks)	**5,543.5**	**6,582.3**	**6,027.6**	**5,784.5**	**5,917.1**	**5,978.3**	**5,827.7**

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

\+ Does not exceed 0.05 MMT CO_2 Eq.

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Emissions from Wood Biomass, Ethanol, and Biodiesel 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 LULUCF.

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

[d] Small amounts of PFC emissions also result from this source.

[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*; 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*. Refer to Table 2-8 for a breakout of emissions and removals for LULUCF by gas and source category.

[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.

Table 2-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (kt)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**5,123,043**	**6,131,833**	**5,569,516**	**5,362,095**	**5,514,018**	**5,565,495**	**5,411,409**
Fossil Fuel Combustion	4,740,343	5,746,942	5,227,061	5,024,643	5,156,523	5,202,300	5,049,763
Electricity Generation	*1,820,818*	*2,400,874*	*2,157,688*	*2,022,181*	*2,038,122*	*2,038,018*	*1,900,673*
Transportation[a]	*1,493,758*	*1,887,033*	*1,707,631*	*1,696,752*	*1,713,002*	*1,742,814*	*1,736,383*

Industrial[a]	*842,473*	*827,999*	*774,951*	*782,929*	*812,228*	*806,075*	*805,496*
Residential	*338,347*	*357,834*	*325,537*	*282,540*	*329,674*	*345,362*	*319,591*
Commercial[a]	*217,393*	*223,480*	*220,381*	*196,714*	*221,030*	*228,666*	*246,241*
U.S. Territories	*27,555*	*49,723*	*40,874*	*43,527*	*42,467*	*41,365*	*41,380*
Non-Energy Use of Fuels	117,585	138,913	109,756	106,750	123,645	118,995	125,526
Iron and Steel Production & Metallurgical Coke Production	101,487	68,047	61,108	55,449	53,348	58,629	48,876
Natural Gas Systems	37,732	30,076	35,662	35,203	38,457	42,351	42,351
Cement Production	33,484	46,194	32,208	35,270	36,369	39,439	39,907
Petrochemical Production	21,326	26,972	26,338	26,501	26,395	26,496	28,062
Lime Production	11,700	14,552	13,982	13,785	14,028	14,210	13,342
Other Process Uses of Carbonates	4,907	6,339	9,335	8,022	10,414	11,811	11,236
Ammonia Production	13,047	9,196	9,292	9,377	9,962	9,619	10,799
Incineration of Waste	7,950	12,469	10,564	10,379	10,398	10,608	10,676
Urea Fertilization	2,417	3,504	4,097	4,267	4,504	4,781	5,032
Carbon Dioxide Consumption	1,472	1,375	4,083	4,019	4,188	4,471	4,296
Liming	4,667	4,349	3,873	5,978	3,907	3,609	3,810
Petroleum Systems	3,553	3,927	4,192	3,876	3,693	3,567	3,567
Soda Ash Production and Consumption	2,822	2,960	2,712	2,763	2,804	2,827	2,789
Aluminum Production	6,831	4,142	3,292	3,439	3,255	2,833	2,767
Ferroalloy Production	2,152	1,392	1,735	1,903	1,785	1,914	1,960
Titanium Dioxide Production	1,195	1,755	1,729	1,528	1,715	1,688	1,635
Glass Production	1,535	1,928	1,299	1,248	1,317	1,336	1,299
Urea Consumption for Non-Agricultural Purposes	3,784	3,653	4,030	4,407	4,014	1,380	1,128
Phosphoric Acid Production	1,529	1,342	1,171	1,118	1,149	1,038	999
Zinc Production	632	1,030	1,286	1,486	1,429	956	933
Lead Production	516	553	538	527	546	459	473
Silicon Carbide Production and Consumption	375	219	170	158	169	173	180
Magnesium Production and Processing	1	3	3	2	2	2	3
Wood Biomass, Ethanol, and Biodiesel Consumption[b]	*219,413*	*230,700*	*276,413*	*276,201*	*299,785*	*307,079*	*291,735*
International Bunker Fuels[c]	*103,463*	*113,139*	*111,660*	*105,805*	*99,763*	*103,201*	*110,751*
CH_4	**31,232**	**27,238**	**26,884**	**26,643**	**26,351**	**26,366**	**26,229**
Enteric Fermentation	6,566	6,755	6,757	6,670	6,619	6,567	6,661
Natural Gas Systems	7,762	6,387	6,180	6,247	6,368	6,501	6,497
Landfills	7,182	5,372	4,760	4,834	4,669	4,663	4,628
Manure Management	1,486	2,254	2,519	2,625	2,530	2,514	2,651
Coal Mining	3,860	2,565	2,849	2,658	2,584	2,593	2,436
Petroleum Systems	2,218	1,840	1,922	1,858	1,778	1,721	1,595
Wastewater Treatment	627	639	613	604	597	592	591
Rice Cultivation	641	667	564	453	454	456	449
Stationary Combustion	339	296	283	265	320	323	280
Abandoned Underground Coal Mines	288	264	257	249	249	253	256
Composting	15	75	75	77	81	84	84
Mobile Combustion[a]	226	113	91	87	85	82	80
Field Burning of Agricultural Residues	9	8	11	11	11	11	11
Petrochemical Production	9	3	2	3	3	5	7
Ferroalloy Production	1	+	+	1	+	1	1
Silicon Carbide Production and Consumption	1	+	+	+	+	+	+

Iron and Steel Production & Metallurgical Coke Production	1	1	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[c]	*7*	*5*	*5*	*4*	*3*	*3*	*3*
N_2O	**1,207**	**1,214**	**1,222**	**1,143**	**1,126**	**1,126**	**1,124**
Agricultural Soil Management	861	872	906	853	841	839	843
Stationary Combustion	40	68	71	72	77	78	78
Manure Management	47	55	58	59	59	59	59
Mobile Combustion[a]	138	120	77	68	62	56	51
Nitric Acid Production	41	38	37	35	36	37	39
Wastewater Treatment	11	15	16	16	16	16	17
Adipic Acid Production	51	24	34	19	13	18	14
N_2O from Product Uses	14	14	14	14	14	14	14
Composting	1	6	6	6	6	6	6
Incineration of Waste	2	1	1	1	1	1	1
Semiconductor Manufacture	+	+	1	1	1	1	1
Field Burning of Agricultural Residues	+	+	+	+	+	+	+
International Bunker Fuels[c]	*3*	*3*	*3*	*3*	*3*	*3*	*3*
HFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Substitution of Ozone Depleting Substances[d]	M	M	M	M	M	M	M
HCFC-22 Production	3	1	1	+	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+
Magnesium Production and Processing	0	0	+	+	+	+	+
PFCs	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Semiconductor Manufacture	M	M	M	M	M	M	M
Aluminum Production	M	M	M	M	M	M	M
Substitution of Ozone Depleting Substances	0	+	+	+	+	+	+
SF_6	**1**	**1**	**+**	**+**	**+**	**+**	**+**
Electrical Transmission and Distribution	1	+	+	+	+	+	+
Magnesium Production and Processing	+	+	+	+	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+
NF_3	+	+	+	+	+	+	+
Semiconductor Manufacture	+	+	+	+	+	+	+

+ Does not exceed 0.5 kt.
M - Mixture of multiple gases
[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.
[b] Emissions from Wood Biomass, Ethanol, and Biodiesel 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 LULUCF.
[c] Emissions from International Bunker Fuels are not included in totals.
[d] Small amounts of PFC emissions also result from this source.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Emissions of all gases can be summed from each source category into a set of five sectors defined by the Intergovernmental Panel on Climate Change (IPCC). Figure 2-4 and Table 2-3 illustrate that over the twenty-six year period of 1990 to 2015, total emissions in the Energy, Industrial Processes and Product Use, and Agriculture sectors grew by 221.0 MMT CO_2 Eq. (4.1 percent), 35.5 MMT CO_2 Eq. (10.4 percent), and 27.0 MMT CO_2 Eq. (5.5 percent), respectively. Emissions from the Waste sector decreased by 59.9 MMT CO_2 Eq. (30.1 percent). Over the same period, estimates of net C sequestration for the Land Use, Land-Use Change, and Forestry sector (magnitude of emissions plus CO_2 removals from all LULUCF categories) increased by 60.7 MMT CO_2 Eq. (7.4 percent decrease in net C sequestration).

Figure 2-4: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO_2 Eq.)

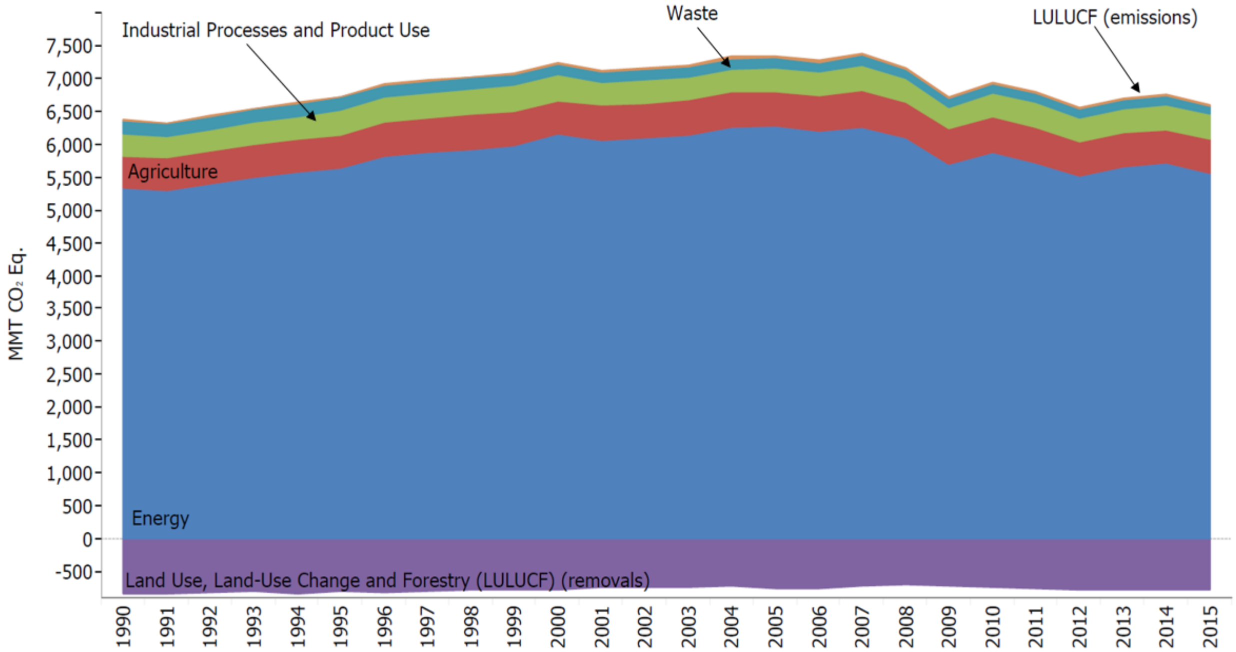


Table 2-3: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (MMT CO_2 Eq.)

Chapter/IPCC Sector	1990	2005	2011	2012	2013	2014	2015
Energy	**5,328.1**	**6,275.3**	**5,721.2**	**5,507.0**	**5,659.1**	**5,704.9**	**5,549.1**
Fossil Fuel Combustion	4,740.3	5,746.9	5,227.1	5,024.6	5,156.5	5,202.3	5,049.8
Natural Gas Systems	231.8	189.8	190.2	191.4	197.7	204.9	204.8
Non-Energy Use of Fuels	117.6	138.9	109.8	106.7	123.6	119.0	125.5
Coal Mining	96.5	64.1	71.2	66.5	64.6	64.8	60.9
Petroleum Systems	59.0	49.9	52.2	50.3	48.2	46.6	43.4
Stationary Combustion	20.4	27.6	28.4	28.0	30.9	31.5	30.1
Mobile Combustion[a]	46.9	38.6	25.1	22.6	20.6	18.6	17.1
Incineration of Waste	8.4	12.9	10.9	10.7	10.7	10.9	11.0
Abandoned Underground Coal Mines	7.2	6.6	6.4	6.2	6.2	6.3	6.4
Industrial Processes and Product Use	**340.4**	**353.4**	**371.0**	**360.9**	**363.7**	**379.8**	**375.9**
Substitution of Ozone Depleting Substances	0.3	99.8	145.4	150.2	154.7	161.3	168.5
Iron and Steel Production & Metallurgical Coke Production	101.5	68.1	61.1	55.5	53.4	58.6	48.9
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9
Petrochemical Production	21.5	27.0	26.4	26.6	26.5	26.6	28.2
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6
Other Process Uses of Carbonates	4.9	6.3	9.3	8.0	10.4	11.8	11.2
Ammonia Production	13.0	9.2	9.3	9.4	10.0	9.6	10.8
Semiconductor Manufacture	3.6	4.7	4.9	4.5	4.1	5.0	5.0
Aluminum Production	28.3	7.6	6.8	6.4	6.2	5.4	4.8

Carbon Dioxide Consumption	1.5	1.4	4.1	4.0	4.2	4.5	4.3
HCFC-22 Production	46.1	20.0	8.8	5.5	4.1	5.0	4.3
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2
Soda Ash Production and Consumption	2.8	3.0	2.7	2.8	2.8	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.9	1.8	1.9	2.0
Titanium Dioxide Production	1.2	1.8	1.7	1.5	1.7	1.7	1.6
Glass Production	1.5	1.9	1.3	1.2	1.3	1.3	1.3
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.0	4.4	4.0	1.4	1.1
Magnesium Production and Processing	5.2	2.7	2.8	1.7	1.5	1.1	1.0
Phosphoric Acid Production	1.5	1.3	1.2	1.1	1.1	1.0	1.0
Zinc Production	0.6	1.0	1.3	1.5	1.4	1.0	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	**495.3**	**526.4**	**541.9**	**525.9**	**516.9**	**514.7**	**522.3**
Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5
Manure Management	51.1	72.9	80.4	83.2	80.8	80.4	84.0
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2
Urea Fertilization	2.4	3.5	4.1	4.3	4.5	4.8	5.0
Liming	4.7	4.3	3.9	6.0	3.9	3.6	3.8
Field Burning of Agricultural Residues	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Waste	**199.3**	**158.2**	**142.6**	**144.4**	**140.4**	**140.2**	**139.4**
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7
Wastewater Treatment	19.1	20.4	20.1	19.9	19.8	19.7	19.7
Composting	0.7	3.5	3.5	3.7	3.9	4.0	4.0
Total Emissions[b]	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**
Land Use, Land-Use Change, and Forestry	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**
Forest Land	(784.3)	(729.8)	(733.8)	(723.6)	(733.5)	(731.8)	(728.7)
Cropland	2.4	(0.7)	4.0	1.3	3.1	4.0	4.7
Grassland	13.8	25.3	9.9	0.8	0.4	0.9	0.4
Wetlands	(3.9)	(5.2)	(3.9)	(4.0)	(4.0)	(4.0)	(4.1)
Settlements	(47.6)	(20.5)	(25.4)	(28.3)	(28.9)	(30.4)	(31.3)
Net Emission (Sources and Sinks)[c]	**5,543.5**	**6,582.3**	**6,027.6**	**5,784.5**	**5,917.1**	**5,978.3**	**5,827.7**

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF.

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Total emissions without LULUCF.

[c] Net emissions with LULUCF.

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

Energy

Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions for the period of 1990 through 2015. Emissions from fossil fuel combustion comprise the vast majority of energy-related emissions, with CO_2 being the primary gas emitted (see Figure 2-5). Due to their relative importance, fossil fuel combustion-related CO_2 emissions are considered in detail in the Energy chapter (see Figure 2-6). In 2015, approximately 82 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 18 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy. A discussion of specific trends related to CO_2 as well as other greenhouse gas emissions from energy consumption is presented in the Energy chapter. Energy-related activities are also responsible for CH_4 and N_2O emissions (42 percent and 12 percent of total U.S. emissions of each gas, respectively). Table 2-4 presents greenhouse gas emissions from the Energy chapter, by source and gas.

Figure 2-5: 2015 Energy Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

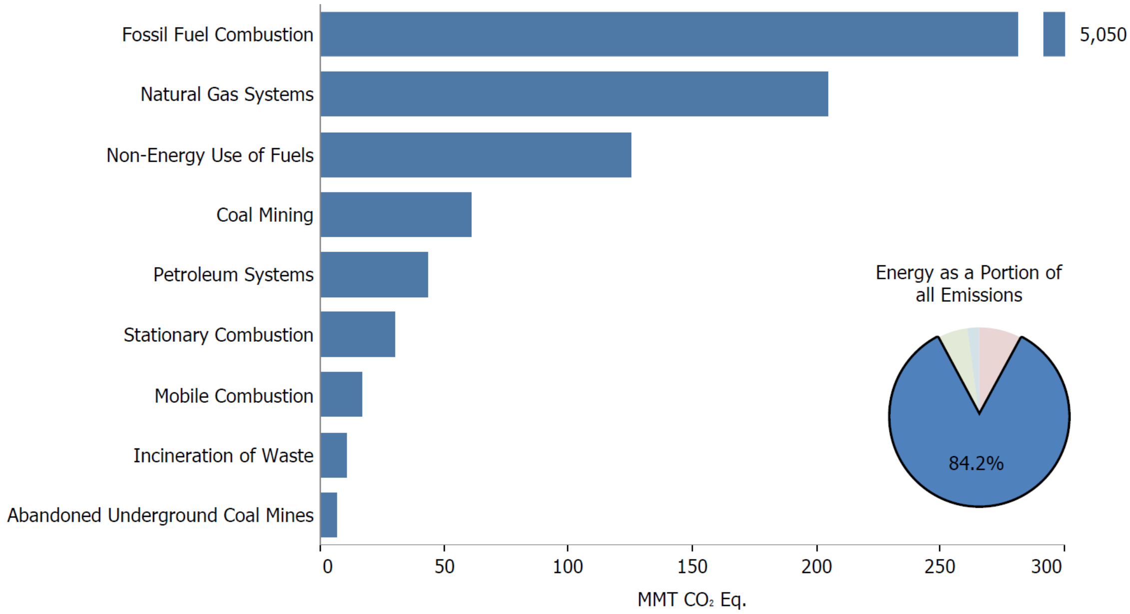


Figure 2-6: 2015 U.S. Fossil Carbon Flows (MMT CO_2 Eq.)

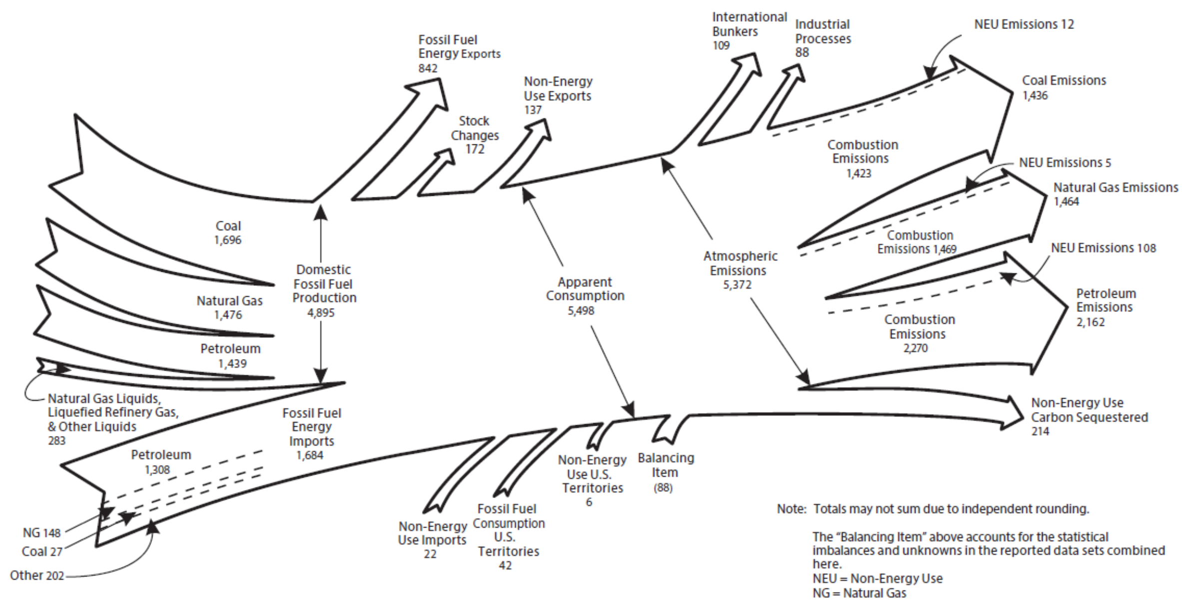


Table 2-4: Emissions from Energy (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**4,907.2**	**5,932.3**	**5,387.2**	**5,180.9**	**5,332.7**	**5,377.8**	**5,231.9**
Fossil Fuel Combustion	4,740.3	5,746.9	5,227.1	5,024.6	5,156.5	5,202.3	5,049.8
Electricity Generation	*1,820.8*	*2,400.9*	*2,157.7*	*2,022.2*	*2,038.1*	*2,038.0*	*1,900.7*
Transportation[a]	*1,493.8*	*1,887.0*	*1,707.6*	*1,696.8*	*1,713.0*	*1,742.8*	*1,736.4*
Industrial[a]	*842.5*	*828.0*	*775.0*	*782.9*	*812.2*	*806.1*	*805.5*
Residential	*338.3*	*357.8*	*325.5*	*282.5*	*329.7*	*345.4*	*319.6*
Commercial[a]	*217.4*	*223.5*	*220.4*	*196.7*	*221.0*	*228.7*	*246.2*
U.S. Territories	*27.6*	*49.7*	*40.9*	*43.5*	*42.5*	*41.4*	*41.4*
Non-Energy Use of Fuels	117.6	138.9	109.8	106.7	123.6	119.0	125.5
Natural Gas Systems	37.7	30.1	35.7	35.2	38.5	42.4	42.4
Incineration of Waste	8.0	12.5	10.6	10.4	10.4	10.6	10.7
Petroleum Systems	3.6	3.9	4.2	3.9	3.7	3.6	3.6
Biomass-Wood[b]	*215.2*	*206.9*	*195.2*	*194.9*	*211.6*	*217.7*	*198.7*
International Bunker Fuels[c]	*103.5*	*113.1*	*111.7*	*105.8*	*99.8*	*103.2*	*110.8*
Biofuels-Ethanol[b]	*4.2*	*22.9*	*72.9*	*72.8*	*74.7*	*76.1*	*78.9*
Biofuels-Biodiesel[b]	*0.0*	*0.9*	*8.3*	*8.5*	*13.5*	*13.3*	*14.1*
CH_4	**367.3**	**286.6**	**289.5**	**284.1**	**284.6**	**286.8**	**278.6**
Natural Gas Systems	194.1	159.7	154.5	156.2	159.2	162.5	162.4
Petroleum Systems	96.5	64.1	71.2	66.5	64.6	64.8	60.9
Coal Mining	55.5	46.0	48.0	46.4	44.5	43.0	39.9
Stationary Combustion	8.5	7.4	7.1	6.6	8.0	8.1	7.0
Abandoned Underground Coal Mines	7.2	6.6	6.4	6.2	6.2	6.3	6.4
Mobile Combustion[a]	5.6	2.8	2.3	2.2	2.1	2.1	2.0
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[c]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O	**53.6**	**56.4**	**44.4**	**42.1**	**41.7**	**40.3**	**38.6**
Stationary Combustion	11.9	20.2	21.3	21.4	22.9	23.4	23.1
Mobile Combustion[a]	41.2	35.7	22.8	20.4	18.5	16.6	15.1
Incineration of Waste	0.5	0.4	0.3	0.3	0.3	0.3	0.3

International Bunker Fuels[c]	*0.9*	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*	*0.9*
Total	**5,328.1**	**6,275.3**	**5,721.2**	**5,507.0**	**5,659.1**	**5,704.9**	**5,549.1**

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Emissions from Wood 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 LULUCF.

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

Note: Totals may not sum due to independent rounding.

Carbon dioxide emissions from fossil fuel combustion are presented in Table 2-5 based on the underlying U.S. energy consumer data collected by the U.S. Energy Information Administration (EIA). Estimates of CO_2 emissions from fossil fuel combustion are calculated from these EIA "end-use sectors" based on total consumption and appropriate fuel properties (any additional analysis and refinement of the EIA data is further explained in the Energy chapter of this report). EIA's fuel consumption data for the electric power sector are comprised of electricity-only and combined-heat-and-power (CHP) plants within the North American Industry Classification System (NAICS) 22 category whose primary business is to sell electricity, or electricity and heat, to the public (nonutility power producers can be included in this sector as long as they meet they electric power sector definition). EIA statistics for the industrial sector include fossil fuel consumption that occurs in the fields of manufacturing, agriculture, mining, and construction. EIA's fuel consumption data for the transportation sector consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. EIA's fuel consumption data for the industrial sector consists of all facilities and equipment used for producing, processing, or assembling goods (EIA includes generators that produce electricity and/or useful thermal output primarily to support on-site industrial activities in this sector). EIA's fuel consumption data for the residential sector consist of living quarters for private households. EIA's fuel consumption data for the commercial sector consist of service-providing facilities and equipment from private and public organizations and businesses (EIA includes generators that produce electricity and/or useful thermal output primarily to support the activities at commercial establishments in this sector). Table 2-5 and Figure 2-7 summarize CO_2 emissions from fossil fuel combustion by end-use sector. Figure 2-8 further describes the total emissions from fossil fuel combustion, separated by end-use sector, including CH_4 and N_2O in addition to CO_2.

Table 2-5: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (MMT CO_2 Eq.)

End-Use Sector	1990	2005	2011	2012	2013	2014	2015
Transportation[a]	**1,496.8**	**1,891.8**	**1,711.9**	**1,700.6**	**1,717.0**	**1,746.9**	**1,740.1**
Combustion	1,493.8	1,887.0	1,707.6	1,696.8	1,713.0	1,742.8	1,736.4
Electricity	3.0	4.7	4.3	3.9	4.0	4.1	3.7
Industrial[a]	**1,529.2**	**1,564.6**	**1,399.6**	**1,375.7**	**1,407.0**	**1,399.3**	**1,355.0**
Combustion	842.5	828.0	775.0	782.9	812.2	806.1	805.5
Electricity	686.7	736.6	624.7	592.8	594.7	593.2	549.6
Residential	**931.4**	**1,214.1**	**1,116.2**	**1,007.8**	**1,064.6**	**1,080.1**	**1,003.9**
Combustion	338.3	357.8	325.5	282.5	329.7	345.4	319.6
Electricity	593.0	856.3	790.7	725.3	734.9	734.7	684.3
Commercial[a]	**755.4**	**1,026.8**	**958.4**	**897.0**	**925.5**	**934.7**	**909.4**
Combustion	217.4	223.5	220.4	196.7	221.0	228.7	246.2
Electricity	538.0	803.3	738.0	700.3	704.5	706.0	663.1
U.S. Territories[b]	**27.6**	**49.7**	**40.9**	**43.5**	**42.5**	**41.4**	**41.4**
Total	**4,740.3**	**5,746.9**	**5,227.1**	**5,024.6**	**5,156.5**	**5,202.3**	**5,049.8**
Electricity Generation	**1,820.8**	**2,400.9**	**2,157.7**	**2,022.2**	**2,038.1**	**2,038.0**	**1,900.7**

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Fuel consumption by U.S. Territories (i.e., American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other U.S. Pacific Islands) is included in this report.
Notes: Combustion-related emissions from electricity generation are allocated based on aggregate national electricity consumption by each end-use sector. Totals may not sum due to independent rounding.

Figure 2-7: 2015 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type (MMT CO_2 Eq.)

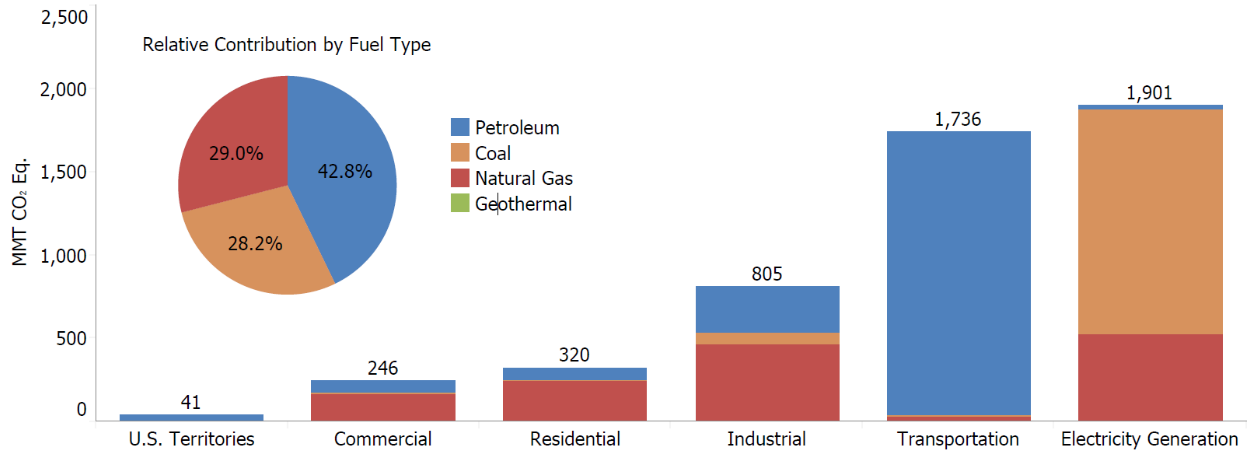
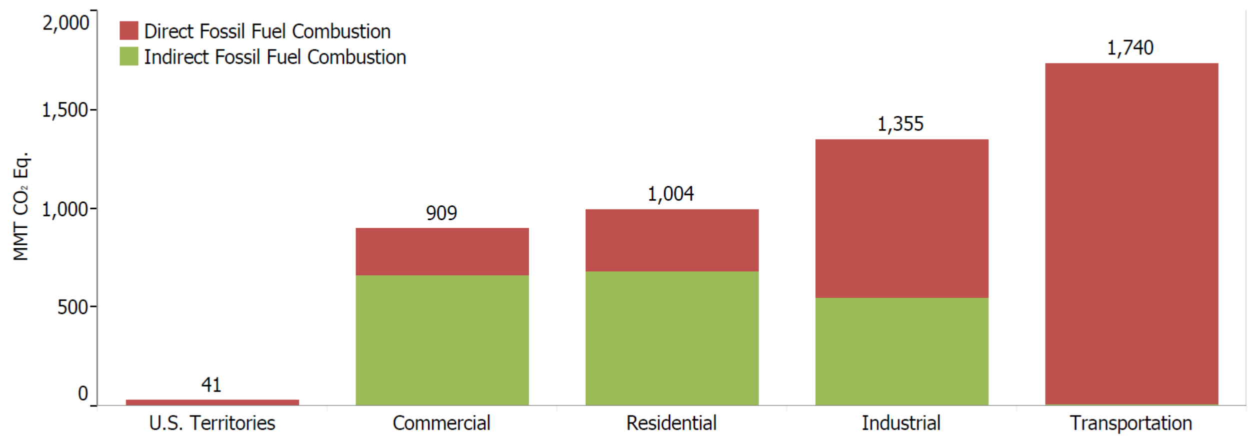
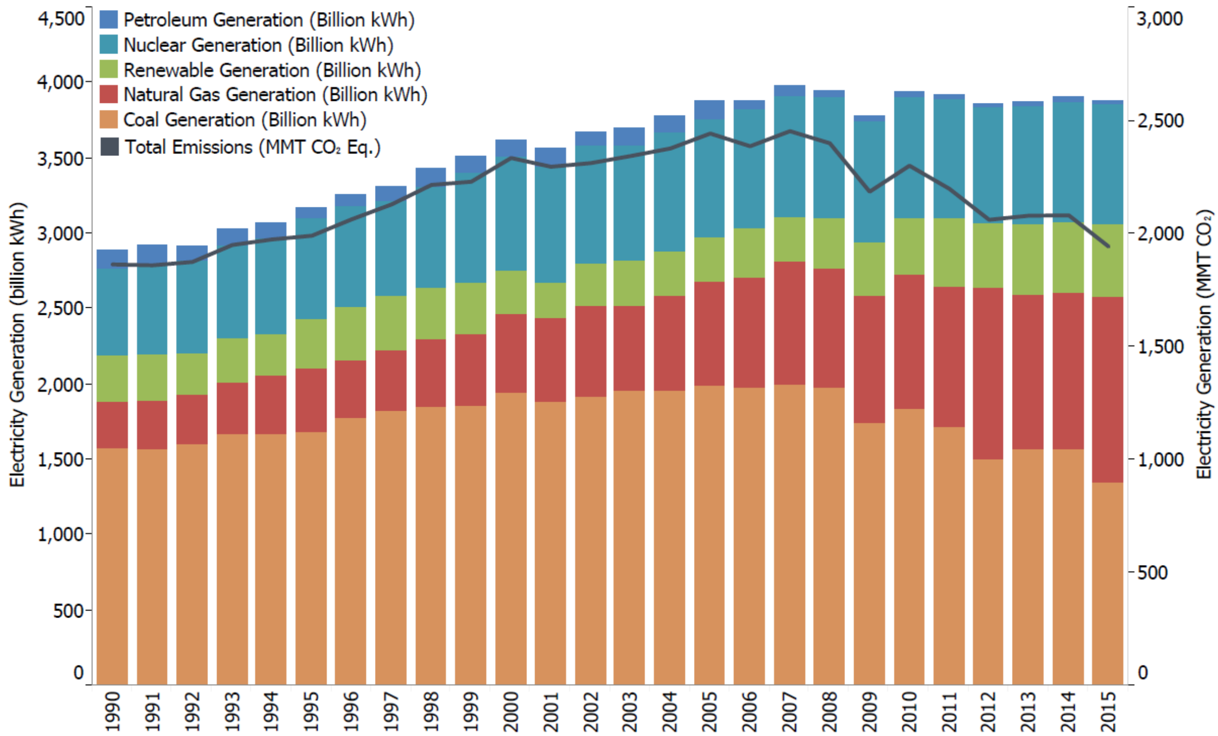


Figure 2-8: 2015 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion (MMT CO_2 Eq.)



The main driver of emissions in the Energy sector is CO_2 from fossil fuel combustion. Electricity generation is the largest emitter of CO_2, and electricity generators consumed 34 percent of U.S. energy from fossil fuels and emitted 38 percent of the CO_2 from fossil fuel combustion in 2015. Changes in electricity demand and the carbon intensity of fuels used for electricity generation have a significant impact on CO_2 emissions. While emissions from the electric power sector have increased by approximately 4 percent since 1990, the carbon intensity of the electric power sector, in terms of CO_2 Eq. per QBtu has significantly decreased by 16 percent during that same timeframe. This decoupling of electricity generation and the resulting emissions is shown below in Figure 2-9.

Figure 2-9: Electricity Generation (Billion kWh) and Emissions (MMT CO_2 Eq.)



Electricity generation emissions can also be allocated to the end-use sectors that are consuming that electricity, as presented in Table 2-5. The transportation end-use sector accounted for 1,740.1 MMT CO_2 Eq. in 2015 or approximately 34 percent of total CO_2 emissions from fossil fuel combustion. The industrial end-use sector accounted for 27 percent of CO_2 emissions from fossil fuel combustion. The residential and commercial end-use sectors accounted for 20 and 18 percent, respectively, of CO_2 emissions from fossil fuel combustion. Both of these end-use sectors were heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances contributing 68 and 73 percent of emissions from the residential and commercial end-use sectors, respectively. Significant trends in emissions from energy source categories over the twenty six-year period from 1990 through 2015 included the following:

- Total CO_2 emissions from fossil fuel combustion increased from 4,740.3 MMT CO_2 Eq. in 1990 to 5,049.8 MMT CO_2 Eq. in 2015 – a 6.5 percent total increase over the twenty six-year period. From 2014 to 2015, these emissions decreased by 152.5 MMT CO_2 Eq. (2.9 percent).

- Methane emissions from natural gas systems and petroleum systems (combined here) decreased from 249.5 MMT CO_2 Eq. in 1990 to 202.3 MMT CO_2 Eq. (47.2 MMT CO_2 Eq. or 18.9 percent) from 1990 to 2015. Natural gas systems CH_4 emissions decreased by 31.6 MMT CO_2 Eq. (16.3 percent) since 1990, largely due to a decrease in emissions from transmission, storage, and distribution. The decrease in transmission and storage emissions is largely due to reduced compressor station emissions (including emissions from compressors and fugitives). The decrease in distribution emissions is largely attributed to increased use of plastic piping, which has lower emissions than other pipe materials, and station upgrades at metering and regulating (M&R) stations. Petroleum systems CH_4 emissions decreased by 15.6 MMT CO_2 Eq. (or 28.1 percent) since 1990. This decrease is due primarily to decreases in emissions from associated gas venting.

- Carbon dioxide emissions from non-energy uses of fossil fuels increased by 7.9 MMT CO_2 Eq. (6.8 percent) from 1990 through 2015. Emissions from non-energy uses of fossil fuels were 125.5 MMT CO_2 Eq. in 2015, which constituted 2.3 percent of total national CO_2 emissions, approximately the same proportion as in 1990.

- Nitrous oxide emissions from stationary combustion increased by 11.2 MMT CO_2 Eq. (94.0 percent) from 1990 through 2015. Nitrous oxide emissions from this source increased primarily as a result of an increase in the number of coal fluidized bed boilers in the electric power sector.
- Nitrous oxide emissions from mobile combustion decreased by 26.1 MMT CO_2 Eq. (63.3 percent) from 1990 through 2015, primarily as a result of N_2O national emission control standards and emission control technologies for on-road vehicles.
- Carbon dioxide emissions from incineration of waste (10.7 MMT CO_2 Eq. in 2015) increased by 2.7 MMT CO_2 Eq. (34.3 percent) from 1990 through 2015, as the volume of plastics and other fossil carbon-containing materials in municipal solid waste grew.

The decrease in CO_2 emissions from fossil fuel combustion was a result of multiple factors, including: (1) substitution from coal to natural gas consumption in the electric power sector; (2) warmer winter conditions in 2015 resulting in a decreased demand for heating fuel in the residential and commercial sectors; and (3) a slight decrease in electricity demand.

Industrial Processes and Product Use

The Industrial Processes and Product Use (IPPU) chapter includes greenhouse gas emissions occurring from industrial processes and from the use of greenhouse gases in products.

Greenhouse gas emissions are produced as the by-products of many non-energy-related industrial activities. For example, industrial processes can chemically transform raw materials, which often release waste gases such as CO_2, CH_4, and N_2O. These processes are shown in Figure 2-10. Industrial processes also release HFCs, PFCs, SF_6, and NF_3 and other fluorinated compounds. In addition to the use of HFCs and some PFCs as substitutes for ozone depleting substances (ODS), fluorinated compounds such as HFCs, PFCs, SF_6, NF_3, and others are employed and emitted by a number of other industrial sources in the United States. These industries include aluminum production, HCFC-22 production, semiconductor manufacture, electric power transmission and distribution, and magnesium metal production and processing. Table 2-6 presents greenhouse gas emissions from industrial processes by source category.

Figure 2-10: 2015 Industrial Processes and Product Use Chapter Greenhouse Gas Sources ($MMT\ CO_2$ Eq.)

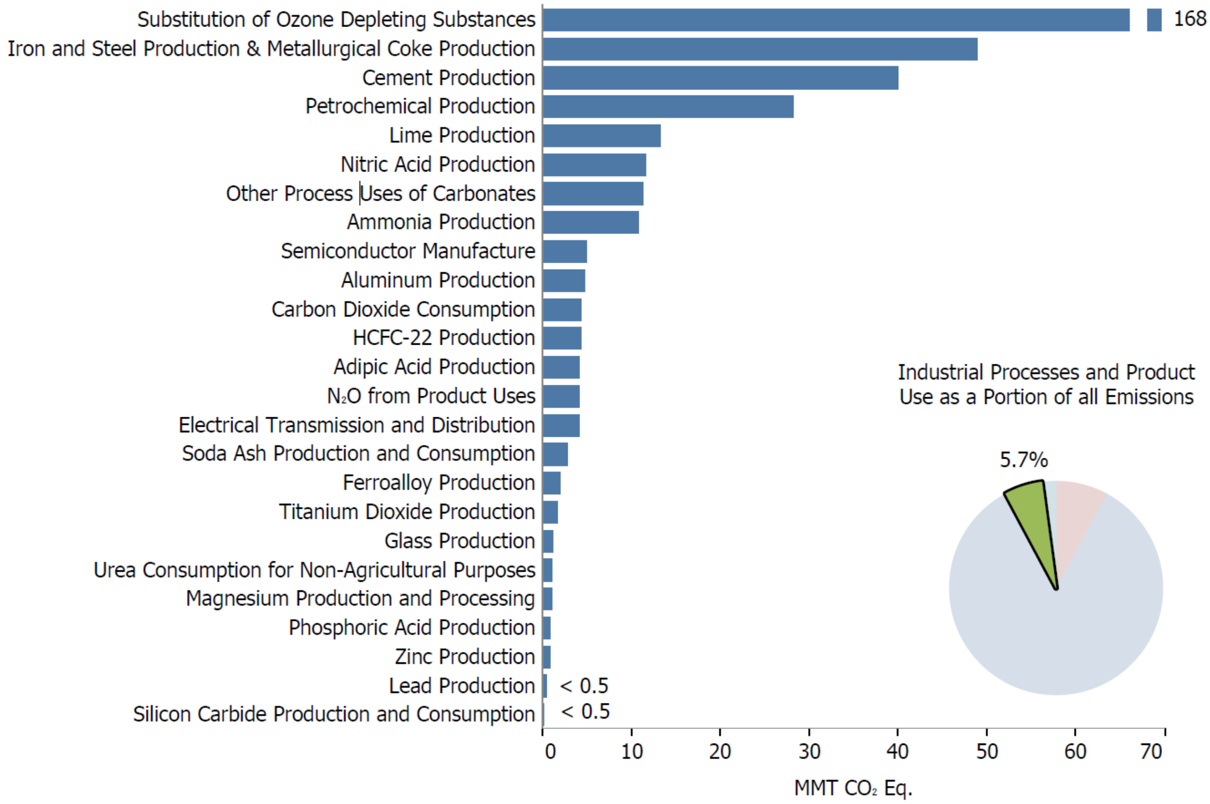


Table 2-6: Emissions from Industrial Processes and Product Use ($MMT\ CO_2$ Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**208.8**	**191.7**	**174.3**	**171.0**	**172.9**	**179.3**	**170.7**
Iron and Steel Production & Metallurgical Coke Production	101.5	68.0	61.1	55.4	53.3	58.6	48.9
Iron and Steel Production	*99.0*	*66.0*	*59.7*	*54.9*	*51.5*	*56.6*	*46.0*
Metallurgical Coke Production	*2.5*	*2.0*	*1.4*	*0.5*	*1.8*	*2.0*	*2.8*
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9
Petrochemical Production	21.3	27.0	26.3	26.5	26.4	26.5	28.1
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3
Other Process Uses of Carbonates	4.9	6.3	9.3	8.0	10.4	11.8	11.2
Ammonia Production	13.0	9.2	9.3	9.4	10.0	9.6	10.8
Carbon Dioxide Consumption	1.5	1.4	4.1	4.0	4.2	4.5	4.3
Soda Ash Production and Consumption	2.8	3.0	2.7	2.8	2.8	2.8	2.8
Aluminum Production	6.8	4.1	3.3	3.4	3.3	2.8	2.8
Ferroalloy Production	2.2	1.4	1.7	1.9	1.8	1.9	2.0
Titanium Dioxide Production	1.2	1.8	1.7	1.5	1.7	1.7	1.6
Glass Production	1.5	1.9	1.3	1.2	1.3	1.3	1.3
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.0	4.4	4.0	1.4	1.1
Phosphoric Acid Production	1.5	1.3	1.2	1.1	1.1	1.0	1.0
Zinc Production	0.6	1.0	1.3	1.5	1.4	1.0	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Magnesium Production and Processing	+	+	+	+	+	+	+
CH_4	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**

Petrochemical Production	0.2	0.1	+	0.1	0.1	0.1	0.2
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Iron and Steel Production & Metallurgical Coke Production	+	+	+	+	+	+	+
Iron and Steel Production	+	+	+	+	+	+	+
Metallurgical Coke Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	**31.6**	**22.8**	**25.6**	**20.4**	**19.0**	**20.8**	**20.3**
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Semiconductor Manufacture	+	0.1	0.2	0.2	0.2	0.2	0.2
HFCs	**46.6**	**120.0**	**154.3**	**155.9**	**159.0**	**166.7**	**173.2**
Substitution of Ozone Depleting Substances[a]	0.3	99.7	145.3	150.2	154.6	161.3	168.5
HCFC-22 Production	46.1	20.0	8.8	5.5	4.1	5.0	4.3
Semiconductor Manufacture	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Magnesium Production and Processing	0.0	0.0	+	+	0.1	0.1	0.1
PFCs	**24.3**	**6.7**	**6.9**	**6.0**	**5.8**	**5.8**	**5.2**
Semiconductor Manufacture	2.8	3.2	3.4	3.0	2.8	3.2	3.2
Aluminum Production	21.5	3.4	3.5	2.9	3.0	2.5	2.0
Substitution of Ozone Depleting Substances	0.0	+	+	+	+	+	+
SF_6	**28.8**	**11.7**	**9.2**	**6.8**	**6.4**	**6.6**	**5.8**
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2
Magnesium Production and Processing	5.2	2.7	2.8	1.6	1.5	1.0	0.9
Semiconductor Manufacture	0.5	0.7	0.4	0.4	0.4	0.7	0.7
NF_3	**+**	**0.5**	**0.7**	**0.6**	**0.6**	**0.5**	**0.6**
Semiconductor Manufacture	+	0.5	0.7	0.6	0.6	0.5	0.6
Total	**340.4**	**353.4**	**371.0**	**360.9**	**363.7**	**379.8**	**375.9**

+ Does not exceed 0.05 MMT CO_2 Eq.
[a] Small amounts of PFC emissions also result from this source.
Note: Totals may not sum due to independent rounding.

Overall, emissions from the IPPU sector increased by 10.4 percent from 1990 to 2015. Significant trends in emissions from IPPU source categories over the twenty-six-year period from 1990 through 2015 included the following:

- Hydrofluorocarbon and perfluorocarbon emissions from ODS substitutes have been increasing from small amounts in 1990 to 168.5 MMT CO_2 Eq. in 2015. This increase was in large part the result of efforts to phase out chlorofluorocarbons (CFCs) and other ODSs in the United States. In the short term, this trend is expected to continue, and will likely continue over the next decade as hydrochlorofluorocarbons (HCFCs), which are interim substitutes in many applications, are themselves phased-out under the provisions of the Copenhagen Amendments to the Montreal Protocol.
- Combined CO_2 and CH_4 emissions from iron and steel production and metallurgical coke production decreased by 16.6 percent to 48.9 MMT CO_2 Eq. from 2014 to 2015, and have declined overall by 52.6 MMT CO_2 Eq. (51.8 percent) from 1990 through 2015, due to restructuring of the industry, technological improvements, and increased scrap steel utilization.
- Carbon dioxide emissions from ammonia production (10.8 MMT CO_2 Eq. in 2015) decreased by 2.2 MMT CO_2 Eq. (17.2 percent) since 1990. Ammonia production relies on natural gas as both a feedstock and a fuel, and as such, market fluctuations and volatility in natural gas prices affect the production of ammonia.
- Urea consumption for non-agricultural purposes (1.1 MMT CO_2 Eq. in 2015) decreased by 2.7 MMT CO_2 Eq. (70.2 percent) since 1990. From 1990 to 2007, emissions increased by 31 percent to a peak of 4.9 MMT CO_2 Eq., before decreasing by 77 percent to 2015 levels.
- Nitrous oxide emissions from adipic acid production were 4.3 MMT CO_2 Eq. in 2015, and have decreased significantly since 1990 due to both the widespread installation of pollution control measures in the late

1990s and plant idling in the late 2000s. Emissions from adipic acid production have decreased by 72.0 percent since 1990 and by 74.8 percent since a peak in 1995.

- PFC emissions from aluminum production decreased by 90.7 percent (19.5 MMT CO_2 Eq.) from 1990 to 2015, due to both industry emission reduction efforts and lower domestic aluminum production.

Agriculture

Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including the following source categories: enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, liming, urea fertilization, and field burning of agricultural residues.

In 2015, agricultural activities were responsible for emissions of 522.3 MMT CO_2 Eq., or 7.9 percent of total U.S. greenhouse gas emissions. Methane, nitrous oxide and carbon dioxide were the primary greenhouse gases emitted by agricultural activities. Methane emissions from enteric fermentation and manure management represented approximately 25.4 percent and 10.1 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2015. Agricultural soil management activities, such as application of synthetic and organic fertilizers, deposition of livestock manure, and growing N-fixing plants, were the largest source of U.S. N_2O emissions in 2015, accounting for 75.1 percent. Carbon dioxide emissions from the application of crushed limestone and dolomite (i.e., soil liming) and urea fertilization represented 0.2 percent of total CO_2 emissions from anthropogenic activities. Figure 2-11 and Table 2-7 illustrate agricultural greenhouse gas emissions by source.

Figure 2-11: 2015 Agriculture Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)

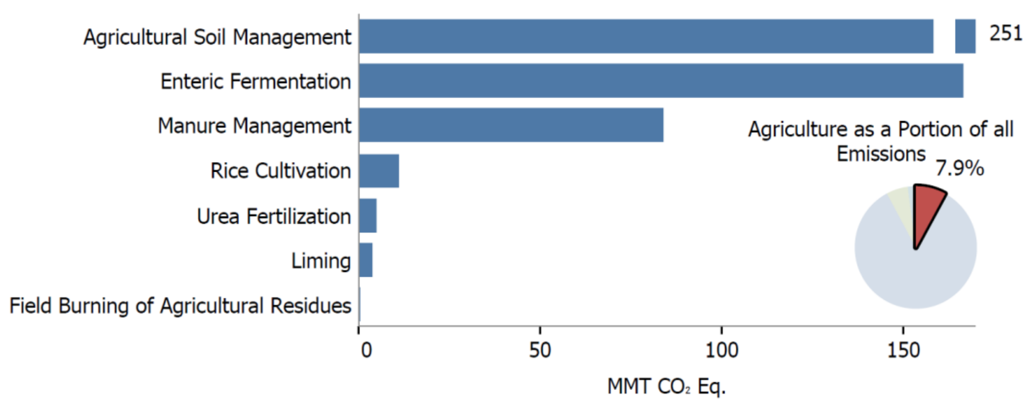


Table 2-7: Emissions from Agriculture (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CO_2	**7.1**	**7.9**	**8.0**	**10.2**	**8.4**	**8.4**	**8.8**
Urea Fertilization	2.4	3.5	4.1	4.3	4.5	4.8	5.0
Liming	4.7	4.3	3.9	6.0	3.9	3.6	3.8
CH_4	**217.6**	**242.1**	**246.3**	**244.0**	**240.4**	**238.7**	**244.3**
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5
Manure Management	37.2	56.3	63.0	65.6	63.3	62.9	66.3
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2
Field Burning of Agricultural Residues	0.2	0.2	0.3	0.3	0.3	0.3	0.3
N_2O	**270.6**	**276.4**	**287.6**	**271.7**	**268.1**	**267.6**	**269.1**
Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3
Manure Management	14.0	16.5	17.4	17.5	17.5	17.5	17.7
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**495.3**	**526.4**	**541.9**	**525.9**	**516.9**	**514.7**	**522.3**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from Agriculture source categories include the following:

- Agricultural soils produced approximately 75.1 percent of N_2O emissions in the United States in 2015. Estimated emissions from this source in 2015 were 251.3 MMT CO_2 Eq. Annual N_2O emissions from agricultural soils fluctuated between 1990 and 2015, although overall emissions were 2.0 percent lower in 2015 than in 1990. Year-to-year fluctuations are largely a reflection of annual variation in weather patterns, synthetic fertilizer use, and crop production.
- Enteric fermentation is the largest anthropogenic source of CH_4 emissions in the United States. In 2015, enteric fermentation CH_4 emissions were 166.5 MMT CO_2 Eq. (25.4 percent of total CH_4 emissions), which represents an increase of 2.4 MMT CO_2 Eq. (1.5 percent) since 1990. This increase in emissions from 1990 to 2015 in enteric fermentation generally follows the increasing trends in cattle populations. From 1990 to 1995, emissions increased and then generally decreased from 1996 to 2004, mainly due to fluctuations in beef cattle populations and increased digestibility of feed for feedlot cattle. Emissions increased from 2005 to 2007, as both dairy and beef populations increased. Research indicates that the feed digestibility of dairy cow diets decreased during this period. Emissions decreased again from 2008 to 2015 as beef cattle populations again decreased.
- Liming and urea fertilization are the only source of CO_2 emissions reported in the Agriculture sector. Estimated emissions from these sources were 3.8 and 5.0 MMT CO_2 Eq., respectively. Liming and urea fertilization emissions increased by 5.6 percent and 5.3 percent, respectively, relative to 2014, and decreased by 18.4 percent and increased by 108.2 percent, respectively since 1990.
- Overall, emissions from manure management increased 64.2 percent between 1990 and 2015. This encompassed an increase of 78.3 percent for CH_4, from 37.2 MMT CO_2 Eq. in 1990 to 66.3 MMT CO_2 Eq. in 2015; and an increase of 26.6 percent for N_2O, from 14.0 MMT CO_2 Eq. in 1990 to 17.7 MMT CO_2 Eq. in 2015. The majority of the increase observed in CH_4 resulted from swine and dairy cattle manure, where emissions increased 58 and 136 percent, respectively, from 1990 to 2015. From 2014 to 2015, there was a 5.4 percent increase in total CH_4 emissions from manure management, mainly due to minor shifts in the animal populations and the resultant effects on manure management system allocations.

Land Use, Land-Use Change, and Forestry

When humans alter the terrestrial biosphere through land use, changes in land use, and land management practices, they also influence the carbon (C) stock fluxes on these lands and cause emissions of CH_4 and N_2O. Overall, managed land is a net sink for CO_2 (C sequestration) in the United States. The drivers of fluxes on managed lands include, for example, forest management practices, tree planting in urban areas, the management of agricultural soils, the landfilling of yard trimmings and food scraps, and activities that cause changes in C stocks in coastal wetlands. The main drivers for net forest sequestration include net forest growth, increasing forest area, and a net accumulation of C stocks in harvested wood pools. The net sequestration in *Settlements Remaining Settlements,* is driven primarily by C stock gains in urban forests through net tree growth and increased urban area, as well as long-term accumulation of C in landfills from additions of yard trimmings and food scraps.

The LULUCF sector in 2015 resulted in a net increase in C stocks (i.e., net CO_2 removals) of 778.7 MMT CO_2 Eq. (Table 2-3).[1] This represents an offset of approximately 11.8 percent of total (i.e., gross) greenhouse gas emissions in 2015. Emissions of CH_4 and N_2O from LULUCF activities in 2015 were 19.7 MMT CO_2 Eq. and represent 0.3 percent of total greenhouse gas emissions.[2] Between 1990 and 2015, total C sequestration in the LULUCF sector decreased by 6.2 percent, primarily due to a decrease in the rate of net C accumulation in forests and an increase in CO_2 emissions from *Land Converted to Settlements*.

Carbon dioxide removals from C stock changes are presented in Table 2-8 along with CH_4 and N_2O emissions for LULUCF source categories. Forest fires were the largest source of CH_4 emissions from LULUCF in 2015, totaling 7.3 MMT CO_2 Eq. (292 kt of CH_4). *Coastal Wetlands Remaining Coastal Wetlands* resulted in CH_4 emissions of 3.6 MMT CO_2 Eq. (143 kt of CH_4). Grassland fires resulted in CH_4 emissions of 0.4 MMT CO_2 Eq. (16 kt of CH_4). *Peatlands Remaining Peatlands*, *Land Converted to Wetlands*, and *Drained Organic Soils* resulted in CH_4 emissions of less than 0.05 MMT CO_2 Eq. each.

Forest fires were also the largest source of N_2O emissions from LULUCF in 2015, totaling 4.8 MMT CO_2 Eq. (16 kt of N_2O). Nitrous oxide emissions from fertilizer application to settlement soils in 2015 totaled to 2.5 MMT CO_2 Eq. (8 kt of N_2O). This represents an increase of 76.6 percent since 1990. Additionally, the application of synthetic fertilizers to forest soils in 2015 resulted in N_2O emissions of 0.5 MMT CO_2 Eq. (2 kt of N_2O). Nitrous oxide emissions from fertilizer application to forest soils have increased by 455 percent since 1990, but still account for a relatively small portion of overall emissions. Grassland fires resulted in N_2O emissions of 0.4 MMT CO_2 Eq. (1 kt of N_2O). *Coastal Wetlands Remaining Coastal Wetlands* and *Drained Organic Soils* resulted in N_2O emissions of 0.1 MMT CO_2 Eq. each (less than 0.5 kt of N_2O), and *Peatlands Remaining Peatlands* resulted in N_2O emissions of less than 0.05 MMT CO_2 Eq. (see Table 2-8).

Table 2-8: U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry (MMT CO_2 Eq.)

Gas/Land-Use Category	1990	2005	2011	2012	2013	2014	2015
Carbon Stock Change[a]	**(830.2)**	**(754.0)**	**(769.1)**	**(779.8)**	**(782.2)**	**(781.1)**	**(778.7)**
Forest Land Remaining Forest Land	(697.7)	(664.6)	(670.0)	(666.9)	(670.8)	(669.3)	(666.2)
Land Converted to Forest Land	(92.0)	(81.4)	(75.8)	(75.2)	(75.2)	(75.2)	(75.2)
Cropland Remaining Cropland	(40.9)	(26.5)	(19.1)	(21.4)	(19.6)	(18.7)	(18.0)
Land Converted to Cropland	43.3	25.9	23.2	22.7	22.7	22.7	22.7
Grassland Remaining Grassland	(4.2)	5.5	(12.5)	(20.8)	(20.5)	(20.4)	(20.9)
Land Converted to Grassland	17.9	19.2	20.7	20.4	20.5	20.5	20.5
Wetlands Remaining Wetlands	(7.6)	(8.9)	(7.6)	(7.7)	(7.8)	(7.8)	(7.8)
Land Converted to Wetlands	+	+	+	+	+	+	+
Settlements Remaining Settlements	(86.2)	(91.4)	(98.7)	(99.2)	(99.8)	(101.2)	(102.1)
Land Converted to Settlements	37.2	68.4	70.7	68.3	68.3	68.3	68.3
CH_4	**6.7**	**13.3**	**11.2**	**14.9**	**11.0**	**11.3**	**11.3**
Forest Land Remaining Forest Land: Forest Fires	3.2	9.4	6.8	10.8	7.2	7.3	7.3
Wetlands Remaining Wetlands: Coastal Wetlands Remaining Coastal Wetlands	3.4	3.5	3.5	3.5	3.6	3.6	3.6

[1] 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.*

[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.

Grassland Remaining Grassland: Grassland Fires	0.1	0.3	0.8	0.6	0.2	0.4	0.4
Forest Land Remaining Forest Land: Drained Organic Soils	+	+	+	+	+	+	+
Land Converted to Wetlands: Land Converted to Coastal Wetlands	+	+	+	+	+	+	+
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
N_2O	**3.9**	**9.7**	**8.7**	**11.1**	**8.2**	**8.4**	**8.4**
Forest Land Remaining Forest Land: Forest Fires	2.1	6.2	4.5	7.1	4.7	4.8	4.8
Settlements Remaining Settlements: Settlement Soils[b]	1.4	2.5	2.6	2.7	2.6	2.5	2.5
Forest Land Remaining Forest Land: Forest Soils[c]	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Grassland Remaining Grassland: Grassland Fires	0.1	0.3	0.9	0.6	0.2	0.4	0.4
Wetlands Remaining Wetlands: Coastal Wetlands Remaining Coastal Wetlands	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Forest Land Remaining Forest Land: Drained Organic Soils	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
LULUCF Emissions[d]	**10.6**	**23.0**	**19.9**	**26.1**	**19.2**	**19.7**	**19.7**
LULUCF Carbon Stock Change[a]	**(830.2)**	**(754.0)**	**(769.1)**	**(779.8)**	**(782.2)**	**(781.1)**	**(778.7)**
LULUCF Sector Net Total[e]	**(819.6)**	**(731.0)**	**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**

+ Absolute value does not exceed 0.05 MMT CO_2 Eq.

[a] 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.*

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

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

[d] 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.

[e] 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.

Other significant trends from 1990 to 2015 in emissions from LULUCF categories include:

- Annual C sequestration by forest land (i.e., annual C stock accumulation in the five C pools and harvested wood products for *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*) has decreased by approximately 6.1 percent since 1990. This is primarily due to decreased C stock gains in *Land Converted to Forest Land* and the harvested wood products pools within *Forest Land Remaining Forest Land*.

- Annual C sequestration from *Settlements Remaining Settlements* (which includes organic soils, urban trees, and landfilled yard trimmings and food scraps) has increased by 18.4 percent over the period from 1990 to 2015. This is primarily due to an increase in urbanized land area in the United States.

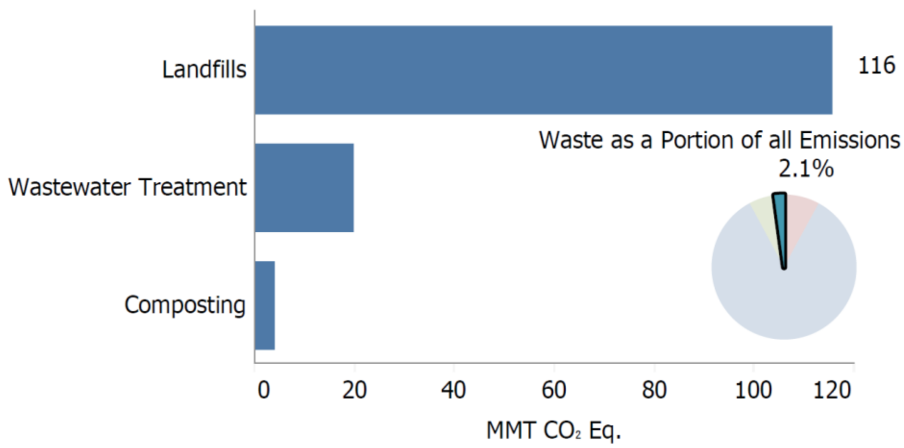
- Annual emissions from *Land Converted to Grassland* increased by approximately 14.4 percent from 1990 to 2015 due to losses in aboveground biomass, belowground biomass, dead wood, and litter C stocks from *Forest Land Converted to Grassland*.

- Annual emissions from *Land Converted to Settlements* increased by approximately 83.5 percent from 1990 to 2015 due to losses in aboveground biomass C stocks from *Forest Land Converted to Settlements* and mineral soils C stocks from *Grassland Converted to Settlements*.

Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 2-12). In 2015, landfills were the third-largest source of U.S. anthropogenic CH_4 emissions, accounting for 17.6 percent of total U.S. CH_4 emissions.[3] Additionally, wastewater treatment accounts for 14.2 percent of Waste emissions, 2.3 percent of U.S. CH_4 emissions, and 1.5 percent of N_2O emissions. Emissions of CH_4 and N_2O from composting grew from 1990 to 2015, and resulted in emissions of 4.0 MMT CO_2 Eq. in 2015. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 2-9.

Figure 2-12: 2015 Waste Chapter Greenhouse Gas Sources (MMT CO_2 Eq.)



Overall, in 2015, waste activities generated emissions of 139.4 MMT CO_2 Eq., or 2.1 percent of total U.S. greenhouse gas emissions.

Table 2-9: Emissions from Waste (MMT CO_2 Eq.)

Gas/Source	1990	2005	2011	2012	2013	2014	2015
CH_4	**195.6**	**152.1**	**136.2**	**137.9**	**133.7**	**133.5**	**132.6**
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7
Wastewater Treatment	15.7	16.0	15.3	15.1	14.9	14.8	14.8
Composting	0.4	1.9	1.9	1.9	2.0	2.1	2.1
N_2O	**3.7**	**6.1**	**6.4**	**6.6**	**6.7**	**6.8**	**6.9**
Wastewater Treatment	3.4	4.4	4.8	4.8	4.9	4.9	5.0
Composting	0.3	1.7	1.7	1.7	1.8	1.9	1.9
Total	**199.3**	**158.2**	**142.6**	**144.4**	**140.4**	**140.2**	**139.4**

Note: Totals may not sum due to independent rounding.

Some significant trends in U.S. emissions from waste source categories include the following:

- From 1990 to 2015, net CH_4 emissions from landfills decreased by 63.8 MMT CO_2 Eq. (35.6 percent), with small increases occurring in interim years. This downward trend in emissions coincided with increased

[3] Landfills also store carbon, due to incomplete degradation of organic materials such as wood products and yard trimmings, as described in the Land Use, Land-Use Change, and Forestry chapter.

landfill gas collection and control systems, and a reduction of decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in MSW landfills over the time series.

- Combined CH_4 and N_2O emissions from composting have generally increased since 1990, from 0.7 MMT CO_2 Eq. to 4.0 MMT CO_2 Eq. in 2015, which represents slightly more than a five-fold increase over the time series. The growth in composting since the 1990s is attributable to primarily two factors: (1) steady growth in population and residential housing, and (2) the enactment of legislation by state and local governments that discouraged the disposal of yard trimmings in landfills.
- From 1990 to 2015, CH_4 and N_2O emissions from wastewater treatment decreased by 0.9 MMT CO_2 Eq. (5.8 percent) and increased by 1.6 MMT CO_2 Eq. (47.0 percent), respectively. Methane emissions from domestic wastewater treatment have decreased since 1999 due to decreasing percentages of wastewater being treated in anaerobic systems, including reduced use of on-site septic systems and central anaerobic treatment systems. Nitrous oxide emissions from wastewater treatment processes gradually increased across the time series as a result of increasing U.S. population and protein consumption.

2.2 Emissions by Economic Sector

Throughout this report, emission estimates are grouped into five sectors (i.e., chapters) defined by the IPCC and detailed above: Energy; Industrial Processes and Product Use; Agriculture; LULUCF; and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines and to promote comparability across countries, it is also useful to characterize emissions according to commonly used economic sector categories: residential, commercial, industry, transportation, electricity generation, and agriculture, as well as U.S. Territories.

Using this categorization, emissions from electricity generation accounted for the largest portion (29 percent) of total U.S. greenhouse gas emissions in 2015. Transportation activities, in aggregate, accounted for the second largest portion (27 percent). Emissions from industry accounted for about 21 percent of total U.S. greenhouse gas emissions in 2015. Emissions from industry have in general declined over the past decade due to a number of factors, including structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. The remaining 22 percent of U.S. greenhouse gas emissions were contributed by the residential, agriculture, and commercial sectors, plus emissions from U.S. Territories. The residential sector accounted for 6 percent, and primarily consisted of CO_2 emissions from fossil fuel combustion. Activities related to agriculture accounted for roughly 9 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation, rather than CO_2 from fossil fuel combustion. The commercial sector accounted for roughly 7 percent of emissions, while U.S. Territories accounted for less than 1 percent. Carbon dioxide was also emitted and sequestered (in the form of C) by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, landfilling of yard trimmings, and changes in C stocks in coastal wetlands.

Table 2-10 presents a detailed breakdown of emissions from each of these economic sectors by source category, as they are defined in this report. Figure 2-13 shows the trend in emissions by sector from 1990 to 2015.

Figure 2-13: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq.)

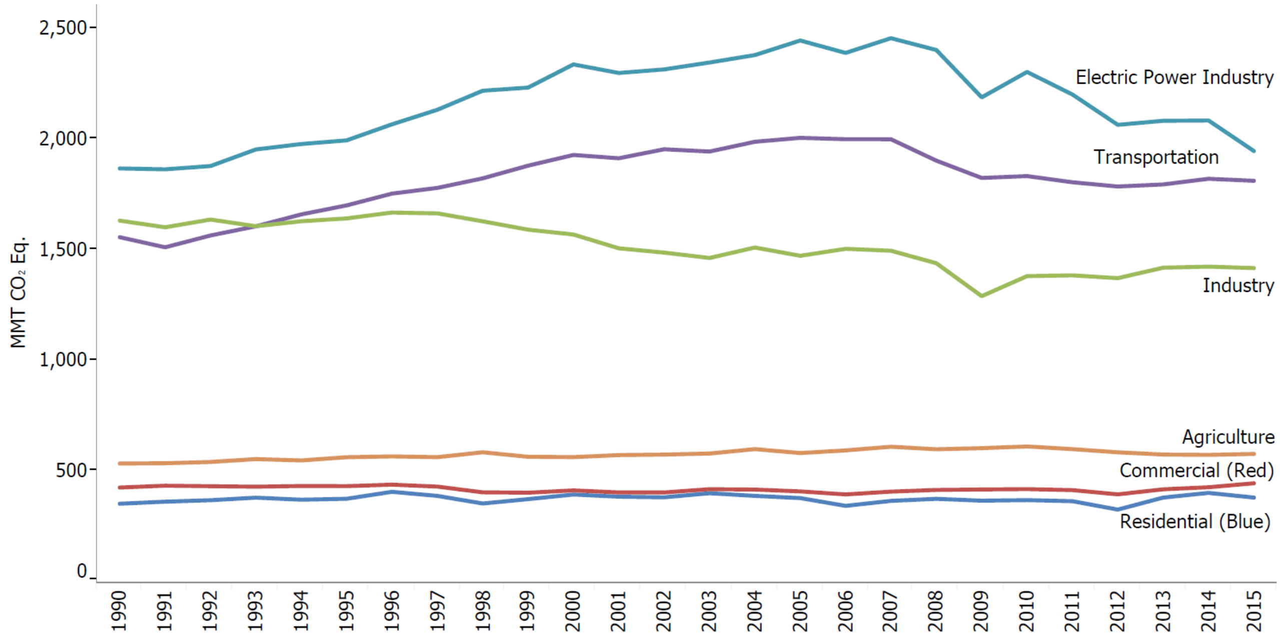


Table 2-10: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2 Eq. and Percent of Total in 2015)

Sector/Source	1990	2005	2011	2012	2013	2014	2015[a]	Percent[a,b]
Electric Power Industry	**1,862.5**	**2,441.6**	**2,197.3**	**2,059.9**	**2,078.2**	**2,079.7**	**1,941.4**	**29.5%**
CO_2 from Fossil Fuel Combustion	1,820.8	2,400.9	2,157.7	2,022.2	2,038.1	2,038.0	1,900.7	28.9%
Stationary Combustion	7.7	16.5	18.0	18.2	19.5	20.0	19.9	0.3%
Incineration of Waste	8.4	12.9	10.9	10.7	10.7	10.9	11.0	0.2%
Other Process Uses of Carbonates	2.5	3.2	4.7	4.0	5.2	5.9	5.6	0.1%
Electrical Transmission and Distribution	23.1	8.3	6.0	4.8	4.6	4.8	4.2	0.1%
Transportation	**1,551.2**	**2,001.0**	**1,800.0**	**1,780.7**	**1,790.2**	**1,815.8**	**1,806.6**	**27.4%**
CO_2 from Fossil Fuel Combustion[a]	1,493.8	1,887.0	1,707.6	1,696.8	1,713.0	1,742.8	1,736.4	26.4%
Substitution of Ozone Depleting Substances	+	67.1	60.2	55.1	49.8	47.2	45.1	0.7%
Mobile Combustion[a]	45.7	36.8	23.2	20.6	18.6	16.6	15.2	0.2%
Non-Energy Use of Fuels	11.8	10.2	9.0	8.3	8.8	9.1	10.0	0.2%
Industry	**1,626.3**	**1,467.1**	**1,378.6**	**1,365.9**	**1,413.4**	**1,418.0**	**1,411.6**	**21.4%**
CO_2 from Fossil Fuel Combustion[a]	811.4	780.6	725.4	731.9	762.2	755.3	758.0	11.5%
Natural Gas Systems	231.8	189.8	190.2	191.4	197.7	204.9	204.8	3.1%
Non-Energy Use of Fuels	100.1	120.6	95.8	93.7	109.4	104.7	110.5	1.7%
Coal Mining	96.5	64.1	71.2	66.5	64.6	64.8	60.9	0.9%
Iron and Steel Production	101.5	68.1	61.1	55.5	53.4	58.6	48.9	0.7%
Petroleum Systems	59.0	49.9	52.2	50.3	48.2	46.6	43.4	0.7%
Cement Production	33.5	46.2	32.2	35.3	36.4	39.4	39.9	0.6%
Petrochemical Production	21.5	27.0	26.4	26.6	26.5	26.6	28.2	0.4%
Substitution of Ozone Depleting Substances	+	7.4	17.1	18.8	20.4	22.3	24.7	0.4%
Lime Production	11.7	14.6	14.0	13.8	14.0	14.2	13.3	0.2%
Nitric Acid Production	12.1	11.3	10.9	10.5	10.7	10.9	11.6	0.2%

Ammonia Production	13.0	9.2	9.3	9.4	10.0	9.6	10.8	0.2%
Abandoned Underground Coal Mines	7.2	6.6	6.4	6.2	6.2	6.3	6.4	0.1%
Other Process Uses of Carbonates	2.5	3.2	4.7	4.0	5.2	5.9	5.6	0.1%
HCFC-22 Production	3.6	4.7	4.9	4.5	4.1	5.0	5.0	0.1%
Semiconductor Manufacture	28.3	7.6	6.8	6.4	6.2	5.4	4.8	0.1%
Aluminum Production	1.5	1.4	4.1	4.0	4.2	4.5	4.3	0.1%
Carbon Dioxide Consumption	46.1	20.0	8.8	5.5	4.1	5.0	4.3	0.1%
Adipic Acid Production	15.2	7.1	10.2	5.5	3.9	5.4	4.3	0.1%
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2	0.1%
Stationary Combustion	4.9	4.6	3.9	3.9	3.9	3.8	3.8	0.1%
Soda Ash Production and Consumption	2.8	3.0	2.7	2.8	2.8	2.8	2.8	+
Ferroalloy Production	2.2	1.4	1.7	1.9	1.8	1.9	2.0	+
Titanium Dioxide Production	1.2	1.8	1.7	1.5	1.7	1.7	1.6	+
Mobile Combustion[a]	0.9	1.3	1.4	1.4	1.5	1.5	1.4	+
Glass Production	1.5	1.9	1.3	1.2	1.3	1.3	1.3	+
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	4.0	4.4	4.0	1.4	1.1	+
Magnesium Production and Processing	5.2	2.7	2.8	1.7	1.5	1.1	1.0	+
Phosphoric Acid Production	1.5	1.3	1.2	1.1	1.1	1.0	1.0	+
Zinc Production	0.6	1.0	1.3	1.5	1.4	1.0	0.9	+
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5	+
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.2	+
Agriculture	**526.7**	**574.3**	**592.0**	**577.6**	**567.5**	**566.1**	**570.3**	**8.7%**
N_2O from Agricultural Soil Management	256.6	259.8	270.1	254.1	250.5	250.0	251.3	3.8%
Enteric Fermentation	164.2	168.9	168.9	166.7	165.5	164.2	166.5	2.5%
Manure Management	51.1	72.9	80.4	83.2	80.8	80.4	84.0	1.3%
CO_2 from Fossil Fuel Combustion[a]	31.0	47.4	49.6	51.1	50.0	50.8	47.5	0.7%
Rice Cultivation	16.0	16.7	14.1	11.3	11.3	11.4	11.2	0.2%
Urea Fertilization	2.4	3.5	4.1	4.3	4.5	4.8	5.0	0.1%
Liming	4.7	4.3	3.9	6.0	3.9	3.6	3.8	0.1%
Mobile Combustion[a]	0.3	0.5	0.5	0.6	0.6	0.6	0.5	+
Field Burning of Agricultural Residues	0.3	0.3	0.4	0.4	0.4	0.4	0.4	+
Stationary Combustion	+	+	+	+	0.1	0.1	0.1	+
Commercial	**418.1**	**400.7**	**406.5**	**387.3**	**410.1**	**419.5**	**437.4**	**6.6%**
CO_2 from Fossil Fuel Combustion[a]	217.4	223.5	220.4	196.7	221.0	228.7	246.2	3.7%
Landfills	179.6	134.3	119.0	120.8	116.7	116.6	115.7	1.8%
Substitution of Ozone Depleting Substances	+	17.6	42.1	44.9	47.4	49.2	50.2	0.8%
Wastewater Treatment	15.7	16.0	15.3	15.1	14.9	14.8	14.8	0.2%
Human Sewage	3.4	4.4	4.8	4.8	4.9	4.9	5.0	0.1%
Composting	0.7	3.5	3.5	3.7	3.9	4.0	4.0	0.1%
Stationary Combustion	1.4	1.4	1.4	1.2	1.3	1.4	1.5	+
Residential	**344.9**	**370.4**	**356.3**	**318.4**	**372.6**	**393.9**	**372.7**	**5.7%**
CO_2 from Fossil Fuel Combustion	338.3	357.8	325.5	282.5	329.7	345.4	319.6	4.9%
Substitution of Ozone Depleting Substances	0.3	7.7	25.9	31.4	37.0	42.6	48.4	0.7%
Stationary Combustion	6.3	4.9	4.9	4.5	5.9	6.0	4.7	0.1%
U.S. Territories	**33.3**	**58.1**	**46.0**	**48.5**	**48.1**	**46.6**	**46.6**	**0.7%**
CO_2 from Fossil Fuel Combustion	27.6	49.7	40.9	43.5	42.5	41.4	41.4	0.6%
Non-Energy Use of Fuels	5.7	8.1	5.0	4.8	5.4	5.1	5.1	0.1%
Stationary Combustion	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
Total Emissions	**6,363.1**	**7,313.3**	**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**	**100.0%**

LULUCF Sector Net Total[c]	**(819.6)**		**(731.0)**		**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**	**(11.5%)**
Net Emissions (Sources and Sinks)	**5,543.5**		**6,582.3**		**6,027.6**	**5,784.5**	**5,917.1**	**5,978.3**	**5,827.7**	**88.5%**

Notes: Total emissions presented without LULUCF. Total net emissions presented with LULUCF.

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

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Percent of total (gross) emissions excluding emissions from LULUCF for 2015.

[c] 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 negative values or sequestration.

Emissions with Electricity Distributed to Economic Sectors

It can also be useful to view greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). The generation, transmission, and distribution of electricity, which is the largest economic sector in the United States, accounted for 29 percent of total U.S. greenhouse gas emissions in 2015. Emissions increased by 4 percent since 1990, as electricity demand grew and fossil fuels remained the dominant energy source for generation. Electricity generation-related emissions decreased from 2014 to 2015 by 6.7 percent, primarily due to decreased CO_2 emissions from fossil fuel combustion due to an increase in natural gas consumption, and decreased coal consumption. Electricity sales to the residential and commercial end-use sectors in 2015 decreased by 0.2 percent and increased by 0.6 percent, respectively. The trend in the residential and commercial sectors can largely be attributed to warmer, less energy-intensive winter conditions compared to 2014. Electricity sales to the industrial sector in 2015 decreased by approximately 1.1 percent. Overall, in 2015, the amount of electricity generated (in kWh) decreased by 0.2 percent from the previous year. This decrease in generation contributed to a reduction in CO_2 emissions from the electric power sector of 6.7 percent, as the consumption of CO_2-intensive coal for electricity generation decreased by 13.9 percent and natural gas generation increased by 18.7 percent. The consumption of petroleum for electricity generation decreased by 6.6 percent in 2015 relative to 2014. Table 2-11 provides a detailed summary of emissions from electricity generation-related activities.

Table 2-11: Electricity Generation-Related Greenhouse Gas Emissions (MMT CO_2 Eq.)

Gas/Fuel Type or Source	1990		2005		2011	2012	2013	2014	2015
CO_2	**1,831.2**		**2,416.5**		**2,172.9**	**2,036.6**	**2,053.7**	**2,054.5**	**1,917.0**
Fossil Fuel Combustion	1,820.8		2,400.9		2,157.7	2,022.2	2,038.1	2,038.0	1,900.7
Coal	*1,547.6*		*1,983.8*		*1,722.7*	*1,511.2*	*1,571.3*	*1,569.1*	*1,350.5*
Natural Gas	*175.3*		*318.8*		*408.8*	*492.2*	*444.0*	*443.2*	*526.1*
Petroleum	*97.5*		*97.9*		*25.8*	*18.3*	*22.4*	*25.3*	*23.7*
Geothermal	*0.4*		*0.4*		*0.4*	*0.4*	*0.4*	*0.4*	*0.4*
Incineration of Waste	8.0		12.5		10.6	10.4	10.4	10.6	10.7
Other Process Uses of Carbonates	2.5		3.2		4.7	4.0	5.2	5.9	5.6
CH_4	**0.3**		**0.5**		**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Stationary Sources (Electricity Generation)	0.3		0.5		0.4	0.4	0.4	0.4	0.4
Incineration of Waste	+		+		+	+	+	+	+
N_2O	**7.8**		**16.4**		**17.9**	**18.1**	**19.4**	**19.9**	**19.8**
Stationary Sources (Electricity Generation)	7.4		16.0		17.6	17.8	19.1	19.6	19.5
Incineration of Waste	0.5		0.4		0.3	0.3	0.3	0.3	0.3
SF_6	**23.1**		**8.3**		**6.0**	**4.8**	**4.6**	**4.8**	**4.2**
Electrical Transmission and Distribution	23.1		8.3		6.0	4.8	4.6	4.8	4.2

Total	**1,862.5**		**2,441.6**		**2,197.3**	**2,059.9**	**2,078.2**	**2,079.7**	**1,941.4**

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] Includes only stationary combustion emissions related to the generation of electricity.

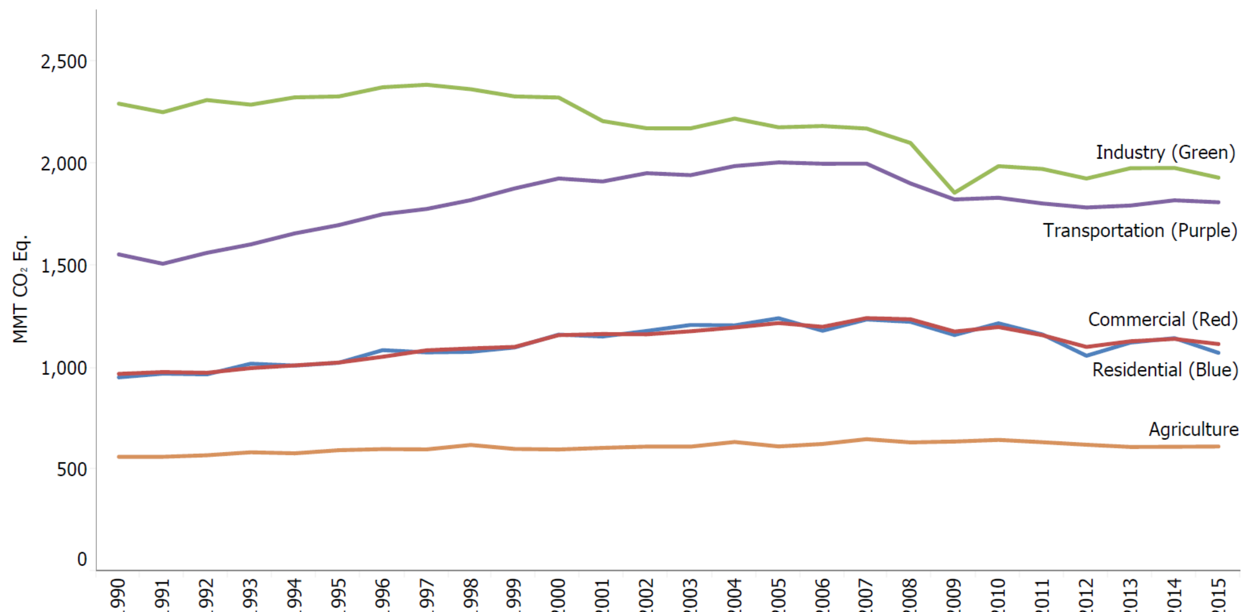
Note: Totals may not sum due to independent rounding.

To distribute electricity emissions among economic end-use sectors, emissions from the source categories assigned to the electricity generation sector were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to each economic sector's share of retail sales of electricity consumption (EIA 2017 and Duffield 2006). These source categories include CO_2 from Fossil Fuel Combustion, CH_4 and N_2O from Stationary Combustion, Incineration of Waste, Other Process Uses of Carbonates, and SF_6 from Electrical Transmission and Distribution Systems. Note that only 50 percent of the Other Process Uses of Carbonates emissions were associated with electricity generation and distributed as described; the remainder of Other Process Uses of Carbonates emissions were attributed to the industrial processes economic end-use sector.[4]

When emissions from electricity are distributed among these sectors, industrial activities account for the largest share of total U.S. greenhouse gas emissions (29.3 percent), followed closely by emissions from transportation (27.5 percent). Emissions from the residential and commercial sectors also increase substantially when emissions from electricity are included. In all sectors except agriculture, CO_2 accounts for more than 82 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels.

Table 2-12 presents a detailed breakdown of emissions from each of these economic sectors, with emissions from electricity generation distributed to them. Figure 2-14 shows the trend in these emissions by sector from 1990 to 2015.

Figure 2-14: U.S. Greenhouse Gas Emissions with Electricity-Related Emissions Distributed to Economic Sectors (MMT CO_2 Eq.)



[4] Emissions were not distributed to U.S. Territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

Table 2-12: U.S. Greenhouse Gas Emissions by Economic Sector and Gas with Electricity-Related Emissions Distributed (MMT CO_2 Eq.) and Percent of Total in 2015

Sector/Gas	1990	2005	2011	2012	2013	2014	2015[a]	Percent[a,b]
Industry	**2,293.9**	**2,178.1**	**1,973.6**	**1,926.7**	**1,977.4**	**1,978.7**	**1,931.1**	**29.3%**
Direct Emissions[a]	**1,626.3**	**1,467.1**	**1,378.6**	**1,365.9**	**1,413.4**	**1,418.0**	**1,411.6**	**21.4%**
CO_2	1,159.2	1,123.7	1,030.6	1,031.6	1,081.5	1,079.3	1,079.5	16.4%
CH_4	355.4	278.4	281.9	277.1	276.3	278.5	271.5	4.1%
N_2O	35.4	26.7	29.2	24.0	22.7	24.4	23.8	0.4%
HFCs, PFCs, SF_6, and NF_3	76.3	38.2	36.8	33.1	32.9	35.7	36.8	0.6%
Electricity-Related	**667.6**	**711.0**	**595.0**	**560.8**	**564.0**	**560.7**	**519.6**	**7.9%**
CO_2	656.4	703.7	588.4	554.4	557.4	553.9	513.1	7.8%
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	+
N_2O	2.8	4.8	4.9	4.9	5.3	5.4	5.3	0.1%
SF_6	8.3	2.4	1.6	1.3	1.2	1.3	1.1	+
Transportation	**1,554.4**	**2,005.9**	**1,804.3**	**1,784.7**	**1,794.3**	**1,820.0**	**1,810.4**	**27.5%**
Direct Emissions[a]	**1,551.2**	**2,001.0**	**1,800.0**	**1,780.7**	**1,790.2**	**1,815.8**	**1,806.6**	**27.4%**
CO_2	1,505.6	1,897.2	1,716.6	1,705.0	1,721.8	1,752.0	1,746.3	26.5%
CH_4	5.4	2.4	1.9	1.8	1.7	1.7	1.6	+
N_2O	40.3	34.3	21.3	18.8	16.9	15.0	13.6	0.2%
HFCs[c]	+	67.1	60.2	55.1	49.8	47.2	45.1	0.7%
Electricity-Related	**3.1**	**4.8**	**4.3**	**3.9**	**4.1**	**4.1**	**3.8**	**0.1%**
CO_2	3.1	4.8	4.3	3.9	4.0	4.1	3.8	0.1%
CH_4	+	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+	+
SF_6	+	+	+	+	+	+	+	+
Commercial	**968.4**	**1,217.6**	**1,158.1**	**1,100.6**	**1,128.5**	**1,139.9**	**1,114.8**	**16.9%**
Direct Emissions[a]	**418.1**	**400.7**	**406.5**	**387.3**	**410.1**	**419.5**	**437.4**	**6.6%**
CO_2	217.4	223.5	220.4	196.7	221.0	228.7	246.2	3.7%
CH_4	196.7	153.2	137.3	138.8	134.7	134.5	133.7	2.0%
N_2O	4.1	6.4	6.7	6.8	7.0	7.1	7.2	0.1%
HFCs	+	17.6	42.1	44.9	47.4	49.2	50.2	0.8%
Electricity-Related	**550.3**	**816.9**	**751.6**	**713.3**	**718.3**	**720.4**	**677.3**	**10.3%**
CO_2	541.1	808.5	743.3	705.3	709.9	711.7	668.8	10.2%
CH_4	0.1	0.2	0.2	0.1	0.2	0.2	0.2	+
N_2O	2.3	5.5	6.1	6.3	6.7	6.9	6.9	0.1%
SF_6	6.8	2.8	2.0	1.7	1.6	1.7	1.4	+%
Residential	**951.5**	**1,241.3**	**1,161.5**	**1,057.2**	**1,122.0**	**1,143.7**	**1,071.6**	**16.3%**
Direct Emissions	**344.9**	**370.4**	**356.3**	**318.4**	**372.6**	**393.9**	**372.7**	**5.7%**
CO_2	338.3	357.8	325.5	282.5	329.7	345.4	319.6	4.9%
CH_4	5.2	4.1	4.0	3.7	5.0	5.0	3.9	0.1%
N_2O	1.0	0.9	0.8	0.7	1.0	1.0	0.8	+
HFCs	0.3	7.7	25.9	31.4	37.0	42.6	48.4	0.7%
Electricity-Related	**606.6**	**870.8**	**805.2**	**738.8**	**749.3**	**749.8**	**698.9**	**10.6%**
CO_2	596.4	861.9	796.3	730.4	740.5	740.7	690.1	10.5%
CH_4	0.1	0.2	0.2	0.2	0.2	0.2	0.2	+
N_2O	2.5	5.8	6.6	6.5	7.0	7.2	7.1	0.1%
SF_6	7.5	2.9	2.2	1.7	1.7	1.7	1.5	+
Agriculture	**561.5**	**612.4**	**633.1**	**620.6**	**609.9**	**610.8**	**612.0**	**9.3%**
Direct Emissions[a]	**526.7**	**574.3**	**592.0**	**577.6**	**567.5**	**566.1**	**570.3**	**8.7%**
CO_2	38.1	55.2	57.6	61.3	58.4	59.2	56.3	0.9%
CH_4	217.7	242.3	246.5	244.2	240.6	238.9	244.5	3.7%
N_2O	270.9	276.8	288.0	272.1	268.5	268.0	269.5	4.1%
Electricity-Related	**34.8**	**38.1**	**41.1**	**43.1**	**42.4**	**44.7**	**41.7**	**0.6%**
CO_2	34.2	37.7	40.6	42.6	41.9	44.1	41.2	0.6%
CH_4	+	+	+	+	+	+	+	+
N_2O	0.1	0.3	0.3	0.4	0.4	0.4	0.4	+
SF_6	0.4	0.1	0.1	0.1	0.1	0.1	0.1	+
U.S. Territories	**33.3**	**58.1**	**46.0**	**48.5**	**48.1**	**46.6**	**46.6**	**0.7%**

Total Emissions	**6,363.1**		**7,313.3**		**6,776.7**	**6,538.3**	**6,680.1**	**6,739.7**	**6,586.7**	**100.0%**
LULUCF Sector Net Total[d]	**(819.6)**		**(731.0)**		**(749.2)**	**(753.8)**	**(763.0)**	**(761.4)**	**(758.9)**	**(11.5%)**
Net Emissions (Sources and Sinks)	**5,543.5**		**6,582.3**		**6,027.6**	**5,784.5**	**5,917.1**	**5,978.3**	**5,827.7**	**88.5%**

Notes: Total emissions presented without LULUCF. Net emissions presented with LULUCF.

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

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Percent of total gross emissions excluding emissions from LULUCF for year 2015.

[c] Includes primarily HFC-134a.

[d] 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: Emissions from electricity generation are allocated based on aggregate electricity consumption in each end-use sector. Totals may not sum due to independent rounding.

Industry

The industry end-use sector includes CO_2 emissions from fossil fuel combustion from all manufacturing facilities, in aggregate. This end-use sector also includes emissions that are produced as a byproduct of the non-energy-related industrial process activities. The variety of activities producing these non-energy-related emissions includes CH_4 emissions from petroleum and natural gas systems, fugitive CH_4 emissions from coal mining, by-product CO_2 emissions from cement manufacture, and HFC, PFC, SF_6, and NF_3 byproduct emissions from semiconductor manufacture, to name a few. Since 1990, industrial sector emissions have declined. The decline has occurred both in direct emissions and indirect emissions associated with electricity use. In theory, emissions from the industrial end-use sector should be highly correlated with economic growth and industrial output, but heating of industrial buildings and agricultural energy consumption are also affected by weather conditions. In addition, structural changes within the U.S. economy that lead to shifts in industrial output away from energy-intensive manufacturing products to less energy-intensive products (e.g., from steel to computer equipment) also have a significant effect on industrial emissions.

Transportation

When electricity-related emissions are distributed to economic end-use sectors, transportation activities accounted for 27.5 percent of U.S. greenhouse gas emissions in 2015. The largest sources of transportation greenhouse gases in 2015 were passenger cars (41.9 percent), freight trucks (22.9 percent), light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (18.0 percent), commercial aircraft (6.6 percent), rail (2.6 percent), other aircraft (2.2 percent), pipelines (2.1 percent), and ships and boats (1.8 percent). These figures include direct CO_2, CH_4, and N_2O emissions from fossil fuel combustion used in transportation and emissions from non-energy use (i.e., lubricants) used in transportation, as well as HFC emissions from mobile air conditioners and refrigerated transport allocated to these vehicle types.

In terms of the overall trend, from 1990 to 2015, total transportation emissions increased due, in large part, to increased demand for travel. The number of vehicle miles traveled (VMT) by light-duty motor vehicles (passenger cars and light-duty trucks) increased 40 percent from 1990 to 2015,[5] as a result of a confluence of factors including population growth, economic growth, urban sprawl, and periods of low fuel prices. The decline in new light-duty vehicle fuel economy between 1990 and 2004 reflected the increasing market share of light-duty trucks, which grew

[5] VMT estimates are based on data from FHWA Highway Statistics Table VM-1 (FHWA 1996 through 2016). In 2011, FHWA changed its methods for estimating VMT by vehicle class, which led to a shift in VMT and emissions among on-road vehicle classes in the 2007 to 2015 time period. In absence of these method changes, light-duty VMT growth between 1990 and 2015 would likely have been even higher.

from about 30 percent of new vehicle sales in 1990 to 48 percent in 2004. Starting in 2005, average new vehicle fuel economy began to increase while light-duty VMT grew only modestly for much of the period. Light-duty VMT grew by less than one percent or declined each year between 2005 and 2013[6] and has since grown a faster rate (1.2 percent from 2013 to 2014, and 2.6 percent from 2014 to 2015). Average new vehicle fuel economy has improved almost every year since 2005 and the truck share decreased to about 33 percent in 2009, and has since varied from year to year between 36 percent and 43 percent. Truck share is about 43 percent of new vehicles in model year 2015 (EPA 2016a). Table 2-13 provides a detailed summary of greenhouse gas emissions from transportation-related activities with electricity-related emissions included in the totals. It is important to note that there was a change in methods between 2014 and 2015 used to estimate gasoline consumption in the transportation sector. In the absence of this change, CO_2 emissions from passenger cars, light-duty trucks, and other on-road vehicles using gasoline would likely have been higher in 2015.[7]

Almost all of the energy consumed for transportation was supplied by petroleum-based products, with more than half being related to gasoline consumption in automobiles and other highway vehicles. Other fuel uses, especially diesel fuel for freight trucks and jet fuel for aircraft, accounted for the remainder. The primary driver of transportation-related emissions was CO_2 from fossil fuel combustion, which increased by 16 percent from 1990 to 2015.[8] This rise in CO_2 emissions, combined with an increase in HFCs from close to zero emissions in 1990 to 45.1 MMT CO_2 Eq. in 2015, led to an increase in overall emissions from transportation activities of 16 percent.[9]

Table 2-13: Transportation-Related Greenhouse Gas Emissions (MMT CO_2 Eq.)

Gas/Vehicle	1990	2005	2011	2012	2013	2014	2015[a]
Passenger Cars	**656.7**	**708.7**	**774.1**	**767.7**	**763.0**	**778.4**	**758.4**
CO_2	629.3	660.1	736.9	735.5	735.5	753.7	735.7
CH_4	3.2	1.2	1.2	1.1	1.1	1.0	1.0
N_2O	24.1	15.7	12.1	10.5	9.2	7.8	6.9
HFCs	0.0	31.7	23.9	20.6	17.3	16.0	14.9
Light-Duty Trucks	**335.2**	**552.2**	**331.5**	**325.1**	**322.2**	**343.7**	**325.1**
CO_2	320.7	503.3	293.8	290.5	290.8	314.4	298.0
CH_4	1.7	0.9	0.4	0.4	0.3	0.3	0.3
N_2O	12.8	14.7	5.6	4.9	4.3	4.0	3.4
HFCs	0.0	33.3	31.7	29.3	26.7	25.0	23.4
Medium- and Heavy-Duty Trucks	**231.4**	**398.9**	**388.4**	**388.8**	**395.8**	**408.3**	**415.0**
CO_2	230.4	396.3	384.7	384.9	391.6	403.9	410.4
CH_4	0.3	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.7	1.2	1.1	1.0	1.0	0.9	0.8
HFCs	0.0	1.2	2.5	2.8	3.1	3.4	3.6
Buses	**8.5**	**12.0**	**16.7**	**17.8**	**18.0**	**19.5**	**19.8**
CO_2	8.4	11.7	16.2	17.3	17.5	18.9	19.3
CH_4	+	+	+	+	+	+	+
N_2O	+	+	0.1	0.1	0.1	0.1	0.1
HFCs	0.0	0.3	0.4	0.4	0.4	0.4	0.4
Motorcycles	**1.8**	**1.7**	**3.6**	**4.2**	**4.0**	**3.9**	**3.7**
CO_2	1.7	1.6	3.6	4.1	3.9	3.9	3.7
CH_4	+	+	+	+	+	+	+

[6] In 2007 and 2008 light-duty VMT decreased 3 percent and 2.3 percent, respectively. Note that the decline in light-duty VMT from 2006 to 2007 is due at least in part to a change in FHWA's methods for estimating VMT. In absence of these method changes, light-duty VMT growth between 2006 and 2007 would likely have been higher. See previous footnote.

[7] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[8] See previous footnote.

[9] See previous footnote.

N_2O	+	+	+	+	+	+	+
Commercial	**110.9**	**134.0**	**115.7**	**114.3**	**115.4**	**116.3**	**120.1**
CO_2	109.9	132.7	114.6	113.3	114.3	115.2	119.0
CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	1.0	1.2	1.1	1.0	1.1	1.1	1.1
Other Aircraft[c]	**78.3**	**59.7**	**34.2**	**32.1**	**34.7**	**35.2**	**40.6**
CO_2	77.5	59.1	33.9	31.8	34.4	34.9	40.2
CH_4	0.1	0.1	+	+	+	+	+
N_2O	0.7	0.5	0.3	0.3	0.3	0.3	0.4
Ships and Boats[d]	**44.9**	**45.0**	**46.5**	**40.2**	**39.5**	**17.6**	**33.1**
CO_2	44.3	44.3	45.5	39.3	38.7	16.9	32.3
CH_4	+	+	+	+	+	+	+
N_2O	0.6	0.6	0.8	0.7	0.7	0.5	0.6
HFCs	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Rail	**38.9**	**51.3**	**46.6**	**45.6**	**46.7**	**48.5**	**46.7**
CO_2	38.5	50.3	44.7	43.4	44.2	45.7	43.6
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.3	0.4	0.3	0.3	0.3	0.4	0.3
HFCs	0.0	0.5	1.5	1.8	2.1	2.4	2.7
Other Emissions from Electricity Generation[e]	0.1	+	+	+	+	+	+
Pipelines[f]	**36.0**	**32.4**	**38.1**	**40.5**	**46.2**	**39.4**	**38.0**
CO_2	36.0	32.4	38.1	40.5	46.2	39.4	38.0
Lubricants	**11.8**	**10.2**	**9.0**	**8.3**	**8.8**	**9.1**	**10.0**
CO_2	11.8	10.2	9.0	8.3	8.8	9.1	10.0
Total Transportation	**1,554.4**	**2,005.9**	**1,804.3**	**1,784.7**	**1,794.3**	**1,820.0**	**1,810.4**
International Bunker Fuels[g]	*104.5*	*114.2*	*112.8*	*106.8*	*100.7*	*104.2*	*111.8*
Ethanol CO_2[h]	*4.1*	*22.4*	*71.5*	*71.5*	*73.4*	*74.9*	*75.9*
Biodiesel CO_2[h]	*0.0*	*0.9*	*8.3*	*8.5*	*13.5*	*13.3*	*14.1*

+ Does not exceed 0.05 MMT CO_2 Eq.

[a] There was a method update in this Inventory for estimating the share of gasoline used in on-road and non-road applications. The change does not impact total U.S. gasoline consumption. It mainly results in a shift in gasoline consumption from the transportation sector to industrial and commercial sectors for 2015, creating a break in the time series. The change is discussed further in the Planned Improvements section of Chapter 3.1.

[b] Consists of emissions from jet fuel consumed by domestic operations of commercial aircraft (no bunkers).

[c] Consists of emissions from jet fuel and aviation gasoline consumption by general aviation and military aircraft.

[d] Fluctuations in emission estimates are associated with fluctuations in reported fuel consumption, and may reflect issues with data sources.

[e] Other emissions from electricity generation are a result of waste incineration (as the majority of municipal solid waste is combusted in "trash-to-steam" electricity generation plants), electrical transmission and distribution, and a portion of Other Process Uses of Carbonates (from pollution control equipment installed in electricity generation plants).

[f] CO_2 estimates reflect natural gas used to power pipelines, but not electricity. While the operation of pipelines produces CH_4 and N_2O, these emissions are not directly attributed to pipelines in the U.S. Inventory.

[g] Emissions from International Bunker Fuels include emissions from both civilian and military activities; these emissions are not included in the transportation totals.

[h] Ethanol and biodiesel CO_2 estimates are presented for informational purposes only. See Section 3.10 and the estimates in Land Use, Land-Use Change, and Forestry (see Chapter 6), in line with IPCC methodological guidance and UNFCCC reporting obligations, for more information on ethanol and biodiesel.

Notes: Passenger cars and light-duty trucks include vehicles typically used for personal travel and less than 8,500 lbs; medium- and heavy-duty trucks include vehicles larger than 8,500 lbs. HFC emissions primarily reflect HFC-134a. Totals may not sum due to independent rounding.

Commercial

The commercial sector is heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Energy-related emissions from the residential and commercial sectors have generally been increasing since 1990, and are often correlated with short-term fluctuations in energy consumption caused by weather conditions, rather than prevailing economic conditions. Landfills and wastewater treatment are included in this sector, with landfill emissions decreasing since 1990 and wastewater treatment emissions decreasing slightly.

Residential

The residential sector is heavily reliant on electricity for meeting energy needs, with electricity consumption for lighting, heating, air conditioning, and operating appliances. The remaining emissions were largely due to the direct consumption of natural gas and petroleum products, primarily for heating and cooking needs. Emissions from the residential sectors have generally been increasing since 1990, and are often correlated with short-term fluctuations in energy consumption caused by weather conditions, rather than prevailing economic conditions. In the long-term, this sector is also affected by population growth, regional migration trends, and changes in housing and building attributes (e.g., size and insulation).

Agriculture

The agriculture end-use sector includes a variety of processes, including enteric fermentation in domestic livestock, livestock manure management, and agricultural soil management. In 2015, agricultural soil management was the largest source of N_2O emissions, and enteric fermentation was the largest source of CH_4 emissions in the United States. This sector also includes small amounts of CO_2 emissions from fossil fuel combustion by motorized farm equipment like tractors. The agriculture sector is less reliant on electricity than the other sectors.

Box 2-1: Methodology for Aggregating Emissions by Economic Sector

In presenting the Economic Sectors in the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, the Inventory expands upon the standard IPCC sectors common for UNFCCC reporting. Discussing greenhouse gas emissions relevant to U.S.-specific sectors improves communication of the report's findings.

In the Electricity Generation economic sector, CO_2 emissions from the combustion of fossil fuels included in the EIA electric utility fuel consuming sector are apportioned to this economic sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA electric utility sector. Additional sources include CO_2, CH_4, and N_2O from waste incineration, as the majority of municipal solid waste is combusted in "trash-to-steam" electricity generation plants. The Electricity Generation economic sector also includes SF_6 from Electrical Transmission and Distribution, and a portion of CO_2 from Other Process Uses of Carbonates (from pollution control equipment installed in electricity generation plants).

In the Transportation economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA transportation fuel consuming sector are apportioned to this economic sector (additional analyses and refinement of the EIA data is further explained in the Energy chapter of this report). Emissions of CH_4 and N_2O from Mobile Combustion are also apportioned to this economic sector based on the EIA transportation fuel consuming sector. Substitution of Ozone Depleting Substances emissions are apportioned based on their specific end-uses within the source category, with emissions from transportation refrigeration/air-conditioning systems to this economic sector. Finally, CO_2 emissions from Non-Energy Uses of Fossil Fuels identified as lubricants for transportation vehicles are included in the Transportation economic sector.

For the Industry economic sector, the CO_2 emissions from the combustion of fossil fuels included in the EIA industrial fuel consuming sector, minus the agricultural use of fuel explained below, are apportioned to this economic sector. The CH_4 and N_2O emissions from stationary and mobile combustion are also apportioned to this economic sector based on the EIA industrial fuel consuming sector, minus emissions apportioned to the Agriculture economic sector described below. Substitution of Ozone Depleting Substances emissions are apportioned based on their specific end-uses within the source category, with most emissions falling within the Industry economic sector. Additionally, all process-related emissions from sources with methods considered within the IPCC IPPU sector have been apportioned to this economic sector. This includes the process-related emissions (i.e., emissions from the actual process to make the material, not from fuels to power the plant) from such activities as Cement Production, Iron and Steel Production and Metallurgical Coke Production, and Ammonia Production. Additionally, fugitive emissions from energy production sources, such as Natural Gas Systems, Coal Mining, and Petroleum Systems are included in the Industry economic sector. A portion of CO_2 from Other Process Uses of Carbonates (from pollution control equipment installed in large industrial facilities) are also included in the Industry economic sector. Finally, all remaining CO_2 emissions from Non-Energy Uses of Fossil Fuels are assumed to be industrial in nature (besides the lubricants for transportation vehicles specified above), and are attributed to the Industry economic sector.

As agriculture equipment is included in EIA's industrial fuel consuming sector surveys, additional data is used to extract the fuel used by agricultural equipment, to allow for accurate reporting in the Agriculture economic sector from all sources of emissions, such as motorized farming equipment. Energy consumption estimates are obtained from Department of Agriculture survey data, in combination with separate EIA fuel sales reports. This supplementary data is used to apportion some of the CO_2 emissions from fossil fuel combustion, and CH_4 and N_2O emissions from stationary and mobile combustion, to the Agriculture economic sector. The other emission sources included in this economic sector are intuitive for the agriculture sectors, such as N_2O emissions from Agricultural Soils, CH_4 from Enteric Fermentation, CH_4 and N_2O from Manure Management, CH_4 from Rice Cultivation, CO_2 emissions from Liming and Urea Application, and CH_4 and N_2O from Forest Fires. Nitrous oxide emissions from the Application of Fertilizers to tree plantations (termed "forest land" by the IPCC) are also included in the Agriculture economic sector.

The Residential economic sector includes the CO_2 emissions from the combustion of fossil fuels reported for the EIA residential sector. Stationary combustion emissions of CH_4 and N_2O are also based on the EIA residential fuel consuming sector. Substitution of Ozone Depleting Substances are apportioned based on their specific end-uses within the source category, with emissions from residential air-conditioning systems to this economic sector. Nitrous oxide emissions from the Application of Fertilizers to developed land (termed "settlements" by the IPCC) are also included in the Residential economic sector.

The Commercial economic sector includes the CO_2 emissions from the combustion of fossil fuels reported in the EIA commercial fuel consuming sector data. Emissions of CH_4 and N_2O from Mobile Combustion are also apportioned to this economic sector based on the EIA transportation fuel consuming sector. Substitution of Ozone Depleting Substances emissions are apportioned based on their specific end-uses within the source category, with emissions from commercial refrigeration/air-conditioning systems apportioned to this economic sector. Public works sources including direct CH_4 from Landfills and CH_4 and N_2O from Wastewater Treatment and Composting are also included in this economic sector.

Box 2-2: Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and non-utilities combined—was the largest source of U.S. greenhouse gas emissions in 2015; (4) emissions per unit of total gross domestic product as a measure of national economic activity; or (5) emissions per capita.

Table 2-14 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. These values represent the relative change in each statistic since 1990. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.2 percent since 1990. Since 1990, this rate is slightly slower than that for total energy and for fossil fuel consumption, and much slower than that for electricity consumption, overall gross domestic product (GDP) and national population (see Table 2-14 and Figure 2-15). These trends vary relative to 2005, when greenhouse gas emissions, total energy and fossil fuel consumption began to peak. Greenhouse gas emissions in the United States have decreased at an average annual rate of 1.0 percent since

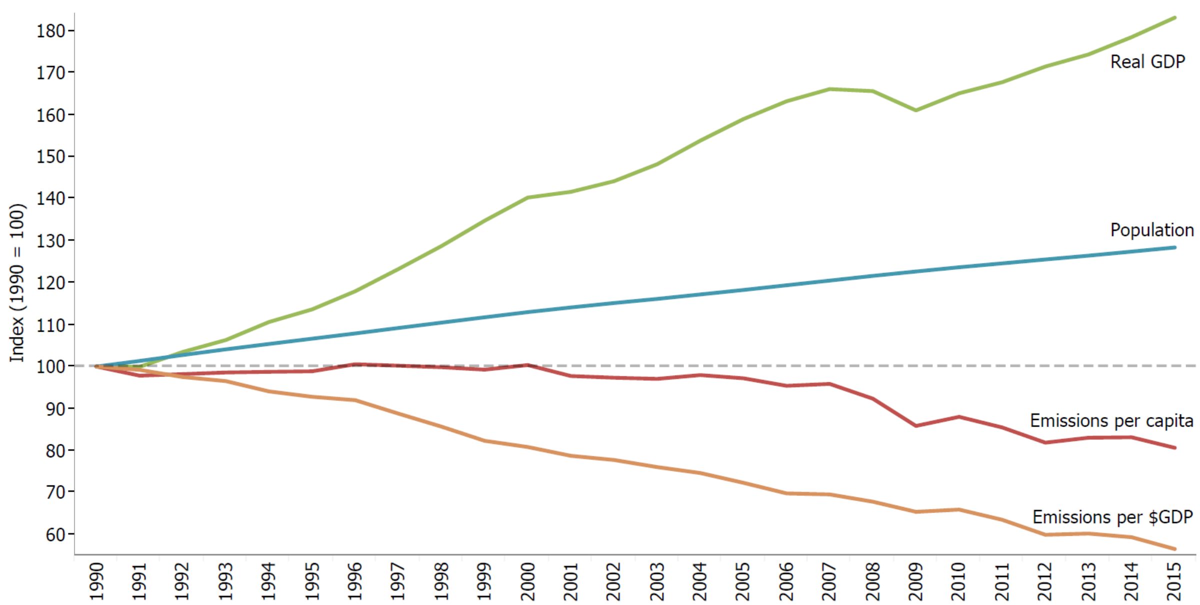
2005. Total energy and fossil fuel consumption have also decreased at slower rates than emissions since 2005, while electricity consumption, GDP, and national population continued to increase.

Table 2-14: Recent Trends in Various U.S. Data (Index 1990 = 100)

Variable	1990	2005	2011	2012	2013	2014	2015	Avg. Annual Change since 1990[a]	Avg. Annual Change since 2005[a]
Greenhouse Gas Emissions[b]	100	115	107	103	105	106	104	0.2%	-1.0%
Energy Consumption[c]	100	118	115	112	115	117	115	0.6%	-0.2%
Fossil Fuel Consumption[c]	100	119	110	107	110	111	110	0.4%	-0.7%
Electricity Consumption[c]	100	134	137	135	136	138	137	1.3%	0.3%
GDP[d]	100	159	168	171	174	178	183	2.5%	1.4%
Population[e]	100	118	125	126	126	127	128	1.0%	0.8%

[a] Average annual growth rate
[b] GWP-weighted values
[c] Energy-content-weighted values (EIA 2017)
[d] Gross Domestic Product in chained 2009 dollars (BEA 2017)
[e] U.S. Census Bureau (2016)

Figure 2-15: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product



Source: BEA (2017), U.S. Census Bureau (2016), and emission estimates in this report.

2.3 Indirect Greenhouse Gas Emissions (CO, NO_x, NMVOCs, and SO_2)

The reporting requirements of the UNFCCC[10] request that information be provided on indirect greenhouse gases, which include CO, NO_x, NMVOCs, and SO_2. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the atmosphere to form compounds that are greenhouse gases. Carbon monoxide is produced when carbon-containing fuels are combusted incompletely. Nitrogen oxides (i.e., NO and NO_2) are created by lightning, fires, fossil fuel combustion, and in the stratosphere from N_2O. Non-methane volatile organic compounds—which include hundreds of organic compounds that participate in atmospheric chemical reactions (i.e., propane, butane, xylene, toluene, ethane, and many others)—are emitted primarily from transportation, industrial processes, and non-industrial consumption of organic solvents. In the United States, SO_2 is primarily emitted from coal combustion for electric power generation and the metals industry. Sulfur-containing compounds emitted into the atmosphere tend to exert a negative radiative forcing (i.e., cooling) and therefore are discussed separately.

One important indirect climate change effect of NMVOCs and NO_x is their role as precursors for tropospheric ozone formation. They can also alter the atmospheric lifetimes of other greenhouse gases. Another example of indirect greenhouse gas formation into greenhouse gases is the interaction of CO with the hydroxyl radical—the major atmospheric sink for CH_4 emissions—to form CO_2. Therefore, increased atmospheric concentrations of CO limit the number of hydroxyl molecules (OH) available to destroy CH_4.

Since 1970, the United States has published estimates of emissions of CO, NO_x, NMVOCs, and SO_2 (EPA 2015),[11] which are regulated under the Clean Air Act. Table 2-15 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Table 2-15: Emissions of NO_x, CO, NMVOCs, and SO_2 (kt)

Gas/Activity	1990		2005		2011	2012	2013	2014	2015
NO_x	**21,790**		**17,443**		**12,482**	**12,038**	**11,387**	**10,810**	**9,971**
Mobile Fossil Fuel Combustion	10,862		10,295		7,294	6,871	6,448	6,024	5,417
Stationary Fossil Fuel Combustion	10,023		5,858		3,807	3,655	3,504	3,291	3,061
Oil and Gas Activities	139		321		622	663	704	745	745
Industrial Processes and Product Use	592		572		452	443	434	424	424
Forest Fires	80		239		172	276	185	188	188
Waste Combustion	82		128		73	82	91	100	100
Grassland Fires	5		21		54	39	13	27	27
Agricultural Burning	6		6		7	7	7	8	8
Waste	+		2		1	2	2	2	2
CO	**132,877**		**75,570**		**52,586**	**54,119**	**48,620**	**46,922**	**44,954**
Mobile Fossil Fuel Combustion	119,360		58,615		38,305	36,153	34,000	31,848	29,881
Forest Fires	2,832		8,486		6,136	9,815	6,655	6,642	6,642
Stationary Fossil Fuel Combustion	5,000		4,648		4,170	4,027	3,884	3,741	3,741
Waste Combustion	978		1,403		1,003	1,318	1,632	1,947	1,947
Industrial Processes and Product Use	4,129		1,557		1,229	1,246	1,262	1,273	1,273
Oil and Gas Activities	302		318		610	666	723	780	780

[10] See <http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf>.

[11] NO_x and CO emission estimates from Field Burning of Agricultural Residues were estimated separately, and therefore not taken from EPA (2016b).

Grassland Fires	84	358	894	657	217	442	442
Agricultural Burning	191	178	234	232	239	240	239
Waste	1	7	5	6	8	9	9
NMVOCs	**20,930**	**13,154**	**11,726**	**11,464**	**11,202**	**10,935**	**10,647**
Industrial Processes and Product Use	7,638	5,849	3,929	3,861	3,793	3,723	3,723
Mobile Fossil Fuel Combustion	10,932	5,724	4,562	4,243	3,924	3,605	3,318
Oil and Gas Activities	554	510	2,517	2,651	2,786	2,921	2,921
Stationary Fossil Fuel Combustion	912	716	599	569	539	507	507
Waste Combustion	222	241	81	94	108	121	121
Waste	673	114	38	45	51	57	57
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA
SO_2	**20,935**	**13,196**	**5,877**	**5,876**	**5,874**	**4,357**	**3,448**
Stationary Fossil Fuel Combustion	18,407	11,541	5,008	5,006	5,005	3,640	2,756
Industrial Processes and Product Use	1,307	831	604	604	604	496	496
Mobile Fossil Fuel Combustion	390	180	108	108	108	93	93
Oil and Gas Activities	793	619	142	142	142	95	70
Waste Combustion	38	25	15	15	15	32	32
Waste	+	1	+	+	+	1	1
Agricultural Burning	NA	NA	NA	NA	NA	NA	NA

+ Does not exceed 0.5 kt.
NA (Not Available)
Note: Totals may not sum due to independent rounding.
Source: (EPA 2015) except for estimates from Field Burning of Agricultural Residues.

Box 2-3: Sources and Effects of Sulfur Dioxide

Sulfur dioxide (SO_2) emitted into the atmosphere through natural and anthropogenic processes affects the earth's radiative budget through its photochemical transformation into sulfate aerosols that can (1) scatter radiation from the sun back to space, thereby reducing the radiation reaching the earth's surface; (2) affect cloud formation; and (3) affect atmospheric chemical composition (e.g., by providing surfaces for heterogeneous chemical reactions). The indirect effect of sulfur-derived aerosols on radiative forcing can be considered in two parts. The first indirect effect is the aerosols' tendency to decrease water droplet size and increase water droplet concentration in the atmosphere. The second indirect effect is the tendency of the reduction in cloud droplet size to affect precipitation by increasing cloud lifetime and thickness. Although still highly uncertain the radiative forcing estimates from both the first and the second indirect effect are believed to be negative, as is the combined radiative forcing of the two (IPCC 2013).

Sulfur dioxide is also a major contributor to the formation of regional haze, which can cause significant increases in acute and chronic respiratory diseases. Once SO_2 is emitted, it is chemically transformed in the atmosphere and returns to the earth as the primary source of acid rain. Because of these harmful effects, the United States has regulated SO_2 emissions in the Clean Air Act.

Electricity generation is the largest anthropogenic source of SO_2 emissions in the United States, accounting for 59.2 percent in 2015. Coal combustion contributes nearly all of those emissions (approximately 92 percent). Sulfur dioxide emissions have decreased in recent years, primarily as a result of electric power generators switching from high-sulfur to low-sulfur coal and installing flue gas desulfurization equipment.

EXHIBIT 3

Task Force on
National Greenhouse Gas Inventories

INTERGOVERNMENTAL PANEL ON CLIMAT

IPCC honoured with the 2007 Nobel Peace Prize

FAQs

Frequently Asked Questions

printabl

1.4. Questions about other Inventory Issues

2. Energy

Q2-10. According to the IPCC Guidelines CO_2 Emissions from the combustion of biomass ar zero in the Energy sector. Do the IPCC Guidelines consider biomass used for energy neutral?

A: The IPCC Guidelines do not automatically consider biomass used for energy as "carbon neutra biomass is thought to be produced sustainably, because:

1) in any time period there may be CO_2 emissions and removals due to the harvesting an bioenergy crops;
2) land use changes caused by biomass production can also result in significant GHG fluxes; anc
3) there may also be significant additional emissions which are estimated and reported in the s they occur e.g.:
   a. from the processing and transportation etc. of the biomass;
   b. direct methane and nitrous oxide emissions from the biomass combustion;
   c. from the production and use of fertilisers and liming if either is used in cultivation of the bio

For example, direct methane and nitrous oxide emissions from biomass combustion for energy use in the energy sector.

Although direct CO_2 emissions from biomass combustion used for energy are recorded as a mer Energy sector these emissions are not included in the Energy sector total. This is to avoid dou because under IPCC guidelines carbon dioxide emissions and removals from the use of biomass f included in the Agriculture, Forestry and Other Land-Use (AFOLU) sector (previously the LULU one of the factors that influence the losses (due to harvest) and any regrowth. Emission and re AFOLU sector include:

- CO_2 emissions or removals due to changes in soil carbon and dead organic matter and
- for perennial crops, CO_2 emissions or removals resulting from changes in biomass stocks c and regrowth.

For annual crops, the IPCC Guidelines assume that biomass carbon stock lost through harvest equal biomass carbon stock gained through regrowth in that same year and so there are no net C or removals from biomass carbon stock changes.

Growing crops for bioenergy can result in land-use changes, both directly through the convers bioenergy production, and indirectly by driving land use changes elsewhere. GHG emissions and to all the land-use changes in a country are reported in the AFOLU sector and can occur for ma the land-use change. These will include emissions from indirect land use change within a country, difficult to separate out only those fluxes due to indirect land use change driven by bioener Indirect changes in terrestrial carbon stocks have considerable uncertainties, are not directly ob complex to model and are difficult to attribute to a single cause, in this case, bioenergy production.

Where biomass is transported across national borders, or land use changes occur across l emissions and removals due to production of biomass for energy use will be reported in the AF the inventory of the country where the biomass is produced. Consequently, provided all countr IPCC guidelines and report to the UNFCCC, all emissions from the use of biomass for energy will and reported.

The overall IPCC approach to bioenergy greenhouse gas emissions at the national level requ coverage of all IPCC sectors, including AFOLU. While individual methodologies and emission fac in the IPCC Guidelines may be relevant for estimating CO_2 emissions from the use of bioenergy a facility or industry, the IPCC approach of not including these emissions in the Energy Sector total interpreted as a conclusion about the sustainability or carbon neutrality of bioenergy. Applyi Guidelines to estimate carbon dioxide emissions from bioenergy at sub-national levels, including f industries or facilities, may require additional data to ensure that relevant emissions and rem harvesting and regrowth of perennial bioenergy crops, land use changes, fertilisation and liming, p transportation are considered at the appropriate level.

3. IPPU

Q3-1. How should we differentiate industrial process emissions and fuel combustion emissions

Q3-2. Can we use “potential emissions” approach for estimation of emissions related to co HFCs, PFCs and SF_6 to prepare national GHG inventories?

Q3-3. Should we deduct quantities of CO_2 for later use and short-term storage (e.g., CO_2 u production, CO_2 used for production of carbonated drinks) from CO_2 emissions?

Q3-4. Do the IPCC Guidelines provide any methodological guidance on absorption of carbonation reaction associated with cement and lime?

Q3-5. Do the IPCC Guidelines provide any guidance on how to collect confidential data/info companies or business associations?

4. AFOLU

Q4-1. What are managed lands?

Q4-2. Should the greenhouse gas emissions/removals in the AFOLU Sector include those occu managed lands? What about those occurring over unmanaged lands?

Q4-3. What are the key greenhouse gases for the AFOLU Sector? What are the processes re emissions/removals of greenhouse gases from the AFOLU Sector?

Q4-4. What are indirect emissions?

Q4-5. What method should the countries use for estimating biomass carbon gain for land rem same land use category if they do not have national carbon stock inventories?

Q4-6. What is the default time period for which an area subject to land use change needs to be t estimation of carbon stock changes in the dead organic matter and soil carbon pools and w

Q4-7. What is meant by the “equivalence” or “synchrony” of CO_2 emissions and removals reasonable to assume equivalence of CO_2 emissions and removals when considering C due to fire?

Q4-8. What are the three different Approaches to data collection and representation of land em AFOLU Sector greenhouse gas estimation? When should they be used? Is there any co between the approaches and the Tiers used for estimation of greenhouse gas emissi AFOLU Sector?

Q4-9. Are there any methodologies available for calculation of N_2O emissions from offsite dec matter from horticultural peat?

Q4-10. What are the variables behind the IPCC default emission factors for enteric fermentation?

Q4-11. Can we obtain removal units (RMUs) under the Kyoto Protocol from avoided emissio with peat mining operations in wetland/peatland area?

Q4-12. Are there any trans-boundary issues involved in estimation of indirect N_2O emissions f managed soil? If so is it reasonable to use country specific emission factors?

Q4-13. Do the guidelines take into account the creation of black or inert carbon stock?

Q4-14. How is the long term storage of carbon in wood products treated?

Q4-15. How are emissions from wetlands treated?

Q4-16. Should a country wish to report the CH_4 emissions from termites, do the IPCC Guide

methodologies to estimate these?

Q4-17. How can N_2O measurements at site level be aggregated to derive a statistically correct na estimate?

Q4-18. Can $Frac_{GASF}$ be further stratified by fertilizer type?

Q4-19. Can $Frac_{GASM}$ be further stratified by manure type?

Q4-20. Can $Frac_{LEACH}$ be further stratified by using climate indices?

Q4-21. Are there default values for calculating soil water holding capacity?

Q4-22. Are there default values for additional crop types not included in Table 11.2 of th Guidelines, e.g. of sugar cane?

Q4-23. How can one derive country-specific service life data for HWP?

Q4-24. Can you point me toward some examples of the use of Tier 3 methodologies in the esti HWP contribution?

Q4-25. How can one perform calibration and verification for Tier 3 methodologies by:

Q4-26. The Equation 12.3, Chapter 12 of 2006 IPCC Guidelines assumes that round wood expo used for solid wood and paper products in the same proportion in the importing domestically. Is this assumption correct and can this estimate be improved if the countri detailed data?

Q4-27. What are 'garden and park waste' HWP categories and what is the correlation of these w sector categories in the Waste spreadsheet?

Q4-28. Where have the definitions for the Equation 12.5, Chapter 12 been given?

Q4-29. What does the line: "The decay of HWP is assumed to be of first order" in Section 12.2.1 mean? Does it just mean loss of carbon due to biological decay?

5. Waste

Q5-1. Should we estimate and report CO_2 emissions from wastewater treatment?

Q5-2. How should we treat CO_2 emissions from waste incineration, where the waste is of mixed non-biogenic material?

Q5-3. Can the mass-balance approach be used for waste disposal sites where historical data are available?

Abbreviations

EXHIBIT 4

Emission Factors for Greenhouse Gas Inventories

Last Modified: 4 April 2014

Red text indicates an update from the 2011 version of this document.

Typically, greenhouse gas emissions are reported in units of carbon dioxide equivalent (CO_2e). Gases are converted to CO_2e by multiplying by their global warming potential (GWP). The emission factors listed in this document have not been converted to CO_2e. To do so, multiply the emissions by the corresponding GWP listed in the table below.

Gas	100-year GWP
CH_4	25
N_2O	298

Source: Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007. See the source note to Table 9 for further explanation.

Table 1 Stationary Combustion Emission Factors

Fuel Type	Heating Value	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor	Unit
	mmBtu per short ton	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per short ton	g CH_4 per short ton	g N_2O per short ton	
Coal and Coke								
Anthracite Coal	25.09	103.69	11	1.6	2,602	276	40	short tons
Bituminous Coal	24.93	93.28	11	1.6	2,325	274	40	short tons
Sub-bituminous Coal	17.25	97.17	11	1.6	1,676	190	28	short tons
Lignite Coal	14.21	97.72	11	1.6	1,389	156	23	short tons
Mixed (Commercial Sector)	21.39	94.27	11	1.6	2,016	235	34	short tons
Mixed (Electric Power Sector)	19.73	95.52	11	1.6	1,885	217	32	short tons
Mixed (Industrial Coking)	26.28	93.90	11	1.6	2,468	289	42	short tons
Mixed (Industrial Sector)	22.35	94.67	11	1.6	2,116	246	36	short tons
Coal Coke	24.80	113.67	11	1.6	2,819	273	40	short tons
Fossil Fuel-derived Fuels (Solid)								
Municipal Solid Waste	9.95	90.70	32	4.2	902	318	42	short tons
Petroleum Coke (Solid)	30.00	102.41	32	4.2	3,072	960	126	short tons
Plastics	38.00	75.00	32	4.2	2,850	1,216	160	short tons
Tires	28.00	85.97	32	4.2	2,407	896	118	short tons
Biomass Fuels (Solid)								
Agricultural Byproducts	8.25	118.17	32	4.2	975	264	35	short tons
Peat	8.00	111.84	32	4.2	895	256	34	short tons
Solid Byproducts	10.39	105.51	32	4.2	1,096	332	44	short tons
Wood and Wood Residuals	17.48	93.80	7.2	3.6	1,640	126	63	short tons
	mmBtu per scf	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per scf	g CH_4 per scf	g N_2O per scf	
Natural Gas								
Natural Gas (per scf)	0.001026	53.06	1.0	0.10	0.05444	0.00103	0.00010	scf
Fossil-derived Fuels (Gaseous)								
Blast Furnace Gas	0.000092	274.32	0.022	0.10	0.02524	0.000002	0.000009	scf
Coke Oven Gas	0.000599	46.85	0.48	0.10	0.02806	0.000288	0.000060	scf
Fuel Gas	0.001388	59.00	3.0	0.60	0.08189	0.004164	0.000833	scf
Propane Gas	0.002516	61.46	0.022	0.10	0.15463	0.000055	0.000252	scf
Biomass Fuels (Gaseous)								
Landfill Gas	0.000485	52.07	3.2	0.63	0.025254	0.001552	0.000306	scf
Other Biomass Gases	0.000655	52.07	3.2	0.63	0.034106	0.002096	0.000413	scf
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per gallon	g CH_4 per gallon	g N_2O per gallon	
Petroleum Products								
Asphalt and Road Oil	0.158	75.36	3.0	0.60	11.91	0.47	0.09	gallon
Aviation Gasoline	0.120	69.25	3.0	0.60	8.31	0.36	0.07	gallon
Butane	0.103	64.77	3.0	0.60	6.67	0.31	0.06	gallon
Butylene	0.105	68.72	3.0	0.60	7.22	0.32	0.06	gallon
Crude Oil	0.138	74.54	3.0	0.60	10.29	0.41	0.08	gallon
Distillate Fuel Oil No. 1	0.139	73.25	3.0	0.60	10.18	0.42	0.08	gallon
Distillate Fuel Oil No. 2	0.138	73.96	3.0	0.60	10.21	0.41	0.08	gallon
Distillate Fuel Oil No. 4	0.146	75.04	3.0	0.60	10.96	0.44	0.09	gallon
Ethane	0.068	59.60	3.0	0.60	4.05	0.20	0.04	gallon
Ethylene	0.058	65.96	3.0	0.60	3.83	0.17	0.03	gallon
Heavy Gas Oils	0.148	74.92	3.0	0.60	11.09	0.44	0.09	gallon
Isobutane	0.099	64.94	3.0	0.60	6.43	0.30	0.06	gallon
Isobutylene	0.103	68.86	3.0	0.60	7.09	0.31	0.06	gallon
Kerosene	0.135	75.20	3.0	0.60	10.15	0.41	0.08	gallon
Kerosene-type Jet Fuel	0.135	72.22	3.0	0.60	9.75	0.41	0.08	gallon
Liquefied Petroleum Gases (LPG)	0.092	61.71	3.0	0.60	5.68	0.28	0.06	gallon
Lubricants	0.144	74.27	3.0	0.60	10.69	0.43	0.09	gallon
Motor Gasoline	0.125	70.22	3.0	0.60	8.78	0.38	0.08	gallon
Naphtha (<401 deg F)	0.125	68.02	3.0	0.60	8.50	0.38	0.08	gallon
Natural Gasoline	0.110	66.88	3.0	0.60	7.36	0.33	0.07	gallon
Other Oil (>401 deg F)	0.139	76.22	3.0	0.60	10.59	0.42	0.08	gallon
Pentanes Plus	0.110	70.02	3.0	0.60	7.70	0.33	0.07	gallon
Petrochemical Feedstocks	0.125	71.02	3.0	0.60	8.88	0.38	0.08	gallon
Petroleum Coke	0.143	102.41	3.0	0.60	14.64	0.43	0.09	gallon
Propane	0.091	62.87	3.0	0.60	5.72	0.27	0.05	gallon
Propylene	0.091	65.95	3.0	0.60	6.00	0.27	0.05	gallon
Residual Fuel Oil No. 5	0.140	72.93	3.0	0.60	10.21	0.42	0.08	gallon
Residual Fuel Oil No. 6	0.150	75.10	3.0	0.60	11.27	0.45	0.09	gallon
Special Naphtha	0.125	72.34	3.0	0.60	9.04	0.38	0.08	gallon
Still Gas	0.143	66.72	3.0	0.60	9.54	0.43	0.09	gallon
Unfinished Oils	0.139	74.54	3.0	0.60	10.36	0.42	0.08	gallon
Used Oil	0.138	74.00	3.0	0.60	10.21	0.41	0.08	gallon
Biomass Fuels (Liquid)								
Biodiesel (100%)	0.128	73.84	1.1	0.11	9.45	0.14	0.01	gallon
Ethanol (100%)	0.084	68.44	1.1	0.11	5.75	0.09	0.01	gallon
Rendered Animal Fat	0.125	71.06	1.1	0.11	8.88	0.14	0.01	gallon
Vegetable Oil	0.120	81.55	1.1	0.11	9.79	0.13	0.01	gallon
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu				
Steam and Hot Water								
Steam and Hot Water		66.33	1.250	0.125				mmBtu

Source:

Solid, gaseous, liquid and biomass fuels: Federal Register (2009) EPA; *40 CFR Parts 86, 87, 89 et al; Mandatory Reporting of Greenhouse Gases; Final Rule*, 30Oct09, 261 pp. Tables C-1 and C-2 at FR pp. 56409-56410. Revised emission factors for selected fuels: Federal Register (2010) EPA; 40 CFR Part 98; Mandatory Reporting of Greenhouse Gases; Final Rule, 17Dec10, 81 pp. With Amendments from Memo: Table of Final 2013 Revisions to the Greenhouse Gas Reporting Rule (PDF) to 40 CFR part 98, subpart C: Table C–1 to Subpart C—Default CO2 Emission Factors and High Heat Values for Various Types of Fuel and Table C–2 to Subpart C—Default CH4 and N2O Emission Factors for Various Types of Fuel.

Steam and Hot Water: EPA (2008) *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance - Indirect Emissions from Purchases/Sales of Electricity and Steam*. Assumption: 80% boiler efficiency and fuel type assumed natural gas. Factors are per mmBtu of steam or hot water purchased.

http://www.epa.gov/ghgreporting/documents/pdf/2013/documents/memo-2013-technical-revisions.pdf

http://www.epa.gov/ghgreporting/reporters/subpartc.html

Table 2 Mobile Combustion CO_2 Emission Factors

Fuel Type	kg CO_2 per unit	Unit
Aviation Gasoline	8.31	gallon
Biodiesel (100%)	9.45	gallon
Compressed Natural Gas (CNG)	0.0545	scf
Diesel Fuel	10.21	gallon
Ethane	4.05	gallon
Ethanol (100%)	5.75	gallon
Jet Fuel (kerosene type)	9.75	gallon
Liquefied Natural Gas (LNG)	4.46	gallon
Liquefied Petroleum Gases (LPG)	5.68	gallon
Methanol	4.10	gallon
Motor Gasoline	8.78	gallon
Propane	5.72	gallon
Residual Fuel Oil	11.27	gallon

Source:

Federal Register (2009) *EPA; 40 CFR Parts 86, 87, 89 et al; Mandatory Reporting of Greenhouse Gases; Final Rule*, 30Oct09, 261 pp. Tables C-1 and C-2. Table of Final 2013 Revisions to the Greenhouse Gas

LNG sourced from: EPA (2008) *Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance - Direct Emissions from Mobile Combustion Sources,* Table B-5.

Methanol sourced from: The Climate Registry (2013); *General Reporting Protocol for the Voluntary Reporting Program Version 2.0*, Default Emission Factors, Table 13.1 US Default CO_2 Emission Factors for Transport Fuels.

Table 3 Mobile Combustion CH_4 and N_2O Emission Factors for On-road Gasoline Vehicles

Vehicle Type	Year	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Gasoline Passenger Cars	1973-74	0.1696	0.0197
	1975	0.1423	0.0443
	1976-77	0.1406	0.0458
	1978-79	0.1389	0.0473
	1980	0.1326	0.0499
	1981	0.0802	0.0626
	1982	0.0795	0.0627
	1983	0.0782	0.0630
	1984-93	0.0704	0.0647
	1994	0.0531	0.0560
	1995	0.0358	0.0473
	1996	0.0272	0.0426
	1997	0.0268	0.0422
	1998	0.0249	0.0393
	1999	0.0216	0.0337
	2000	0.0178	0.0273
	2001	0.0110	0.0158
	2002	0.0107	0.0153
	2003	0.0114	0.0135
	2004	0.0145	0.0083
	2005	0.0147	0.0079
	2006	0.0161	0.0057
	2007	0.0170	0.0041
	2008	0.0172	0.0038
	2009-present	0.0173	0.0036
Gasoline Light-duty Trucks (Vans, Pickup Trucks, SUVs)	1973-74	0.1908	0.0218
	1975	0.1634	0.0513
	1976	0.1594	0.0555
	1977-78	0.1614	0.0534
	1979-80	0.1594	0.0555
	1981	0.1479	0.0660
	1982	0.1442	0.0681
	1983	0.1368	0.0722
	1984	0.1294	0.0764
	1985	0.1220	0.0806
	1986	0.1146	0.0848
	1987-93	0.0813	0.1035
	1994	0.0646	0.0982
	1995	0.0517	0.0908
	1996	0.0452	0.0871
	1997	0.0452	0.0871
	1998	0.0391	0.0728
	1999	0.0321	0.0564
	2000	0.0346	0.0621
	2001	0.0151	0.0164
	2002	0.0178	0.0228
	2003	0.0155	0.0114
	2004	0.0152	0.0132
	2005	0.0157	0.0101
	2006	0.0159	0.0089
	2007	0.0161	0.0079
	2008-present	0.0163	0.0066
Gasoline Heavy-duty Vehicles	<1981	0.4604	0.0497
	1982-84	0.4492	0.0538
	1985-86	0.4090	0.0515
	1987	0.3675	0.0849
	1988-1989	0.3492	0.0933
	1990-1995	0.3246	0.1142
	1996	0.1278	0.1680
	1997	0.0924	0.1726
	1998	0.0641	0.1693
	1999	0.0578	0.1435
	2000	0.0493	0.1092
	2001	0.0528	0.1235
	2002	0.0546	0.1307
	2003	0.0533	0.1240
	2004	0.0341	0.0285
	2005	0.0326	0.0177
	2006	0.0327	0.0171
	2007	0.0330	0.0153
	2008-present	0.0333	0.0134

Source: EPA (2014) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. All values are calculated from Tables A-101 through A-105.

Table 4 Mobile Combustion CH_4 and N_2O Emission Factors for On-road Diesel and Alternative Fuel Vehicles

Vehicle Type	Vehicle Year	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Diesel Passenger Cars	1960-1982	0.0006	0.0012
	1983-1995	0.0005	0.0010
	1996-present	0.0005	0.0010
Diesel Light-duty Trucks	1960-1982	0.0011	0.0017
	1983-1995	0.0009	0.0014
	1996-present	0.0010	0.0015
Diesel Medium- and Heavy-duty Vehicles	1960-present	0.0051	0.0048
Gasoline Motorcycles	1960-1995	0.0899	0.0087
	1996-present	0.0672	0.0069
CNG Light-duty Vehicles		0.7370	0.0500
CNG Heavy-duty Vehicles		1.9660	0.1750
CNG Buses		1.9660	0.1750
LPG Light-duty Vehicles		0.0370	0.0670
LPG Heavy-duty Vehicles		0.0660	0.1750
LNG Heavy-duty Vehicles		1.9660	0.1750
Ethanol Light-duty Vehicles		0.0550	0.0670
Ethanol Heavy-duty Vehicles		0.1970	0.1750
Ethanol Buses		0.1970	0.1750

Source: EPA (2014) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. All values are calculated from Tables A-104 through A-106.

Table 5 Mobile Combustion CH_4 and N_2O Emission Factors for Non-road Vehicles

Vehicle Type	CH_4 Factor (g / gallon)	N_2O Factor (g / gallon)
LPG Non-Highway Vehicles	0.50	0.22
Residual Oil Ships and Boats	0.11	0.57
Diesel Ships and Boats	0.06	0.45
Gasoline Ships and Boats	0.64	0.22
Diesel Locomotives	0.80	0.26
Gasoline Agricultural Equip.	1.26	0.22
Diesel Agricultural Equip.	1.44	0.26
Gasoline Construction Equip.	0.50	0.22
Diesel Construction Equip.	0.57	0.26
Jet Fuel Aircraft	0.00	0.30
Aviation Gasoline Aircraft	7.06	0.11
Biodiesel Vehicles	0.57	0.26
Other Diesel Sources	0.57	0.26
Other Gasoline Sources	0.50	0.22

Source: EPA (2014) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. All values are calculated from Table A-107.
Note: LPG non-highway vehicles assumed equal to other gasoline sources. Biodiesel vehicles assumed equal to other diesel sources.

Table 6 Electricity Emission Factors

eGRID Subregion	Total output emission factors			Non-baseload emission factors		
	CO_2 Factor ($lb\ CO_2$/MWh)	CH_4 Factor ($lb\ CH_4$/MWh)	N_2O Factor ($lb\ N_2O$/MWh)	CO_2 Factor ($lb\ CO_2$/MWh)	CH_4 Factor ($lb\ CH_4$/MWh)	N_2O Factor ($lb\ N_2O$/MWh)
AKGD (ASCC Alaska Grid)	1,256.87	0.02608	0.00718	1,387.37	0.03405	0.00693
AKMS (ASCC Miscellaneous)	448.57	0.01874	0.00368	1,427.76	0.05997	0.01180
AZNM (WECC Southwest)	1,177.61	0.01921	0.01572	1,210.44	0.02188	0.00986
CAMX (WECC California)	610.82	0.02849	0.00603	932.82	0.03591	0.00455
ERCT (ERCOT All)	1,218.17	0.01685	0.01407	1,181.70	0.02012	0.00763
FRCC (FRCC All)	1,196.71	0.03891	0.01375	1,277.42	0.03873	0.01083
HIMS (HICC Miscellaneous)	1,330.16	0.07398	0.01388	1,690.72	0.10405	0.01912
HIOA (HICC Oahu)	1,621.86	0.09930	0.02241	1,588.23	0.11948	0.02010
MROE (MRO East)	1,610.80	0.02429	0.02752	1,755.66	0.03153	0.02799
MROW (MRO West)	1,536.36	0.02853	0.02629	2,054.55	0.05986	0.03553
NEWE (NPCC New England)	722.07	0.07176	0.01298	1,106.82	0.06155	0.01207
NWPP (WECC Northwest)	842.58	0.01605	0.01307	1,340.34	0.04138	0.01784
NYCW (NPCC NYC/Westchester)	622.42	0.02381	0.00280	1,131.63	0.02358	0.00244
NYLI (NPCC Long Island)	1,336.11	0.08149	0.01028	1,445.94	0.03403	0.00391
NYUP (NPCC Upstate NY)	545.79	0.01630	0.00724	1,253.77	0.03683	0.01367
RFCE (RFC East)	1,001.72	0.02707	0.01533	1,562.72	0.03593	0.02002
RFCM (RFC Michigan)	1,629.38	0.03046	0.02684	1,744.52	0.03231	0.02600
RFCW (RFC West)	1,503.47	0.01820	0.02475	1,982.87	0.02450	0.03107
RMPA (WECC Rockies)	1,896.74	0.02266	0.02921	1,808.03	0.02456	0.02289
SPNO (SPP North)	1,799.45	0.02081	0.02862	1,951.83	0.02515	0.02690
SPSO (SPP South)	1,580.60	0.02320	0.02085	1,436.29	0.02794	0.01210
SRMV (SERC Mississippi Valley)	1,029.82	0.02066	0.01076	1,222.40	0.02771	0.00663
SRMW (SERC Midwest)	1,810.83	0.02048	0.02957	1,964.98	0.02393	0.02965
SRSO (SERC South)	1,354.09	0.02282	0.02089	1,574.37	0.02652	0.02149
SRTV (SERC Tennessee Valley)	1,389.20	0.01770	0.02241	1,873.83	0.02499	0.02888
SRVC (SERC Virginia/Carolina)	1,073.65	0.02169	0.01764	1,624.71	0.03642	0.02306
US Average	1,232.35	0.02414	0.01826	1,520.20	0.03127	0.01834

Source: EPA Year 2010 eGRID 9th edition Version 1.0 February 2014.
Note: Total output emission factors are used for quantifying emissions from purchased electricity. Non-baseload emission factors are used for quantifying the emission reductions from purchased green power.

This is a representational map; many of the boundaries shown on this map are approximate because they are based on companies, not on strictly geographical boundaries.
Source: EPA Year 2010 eGRID 9th edition Version 1.0 February 2014.

Table 7 Business Travel Emission Factors

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Passenger Car [A]	0.368	0.018	0.013	vehicle-mile
Light-duty Truck [B]	0.501	0.024	0.019	vehicle-mile
Motorcycle	0.197	0.070	0.007	vehicle-mile
Intercity Rail (i.e. Amtrak) [C]	0.144	0.0085	0.0032	passenger-mile
Commuter Rail [D]	0.174	0.0084	0.0035	passenger-mile
Transit Rail (i.e. Subway, Tram) [E]	0.133	0.0026	0.0020	passenger-mile
Bus	0.058	0.0007	0.0004	passenger-mile
Air Travel - Short Haul (< 300 miles)	0.275	0.0091	0.0087	passenger-mile
Air Travel - Medium Haul (>= 300 miles, < 2300 miles)	0.162	0.0008	0.0052	passenger-mile
Air Travel - Long Haul (>= 2300 miles)	0.191	0.0008	0.0060	passenger-mile

Source:
CO_2, CH_4, and N_2O emissions data for highway vehicles are from Table 2-15 of the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012. Vehicle-miles and passenger-miles data for highway vehicles are from Table VM-1 of the Federal Highway Administration Highway Statistics 2012.
Fuel consumption data and passenger-miles data for rail are from Tables A.14 to A.16 and 9.10 to 9.12 of the Transportation Energy Data Book: Edition 32. Fuel consumption was converted to emissions by using fuel and electricity emission factors presented in the tables above.

Notes:
[A] Passenger car: includes passenger cars, minivans, SUVs, and small pickup trucks (vehicles with wheelbase less than 121 inches).
[B] Light-duty truck: includes full-size pickup trucks, full-size vans, and extended-length SUVs (vehicles with wheelbase greater than 121 inches).
[C] Intercity rail: long-distance rail between major cities, such as Amtrak
[D] Commuter rail: rail service between a central city and adjacent suburbs (also called regional rail or suburban rail)
[E] Transit rail: rail typically within an urban center, such as subways, elevated railways, metropolitan railways (metro), streetcars, trolley cars, and tramways.

Table 8 Product Transport Emission Factors

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Medium- and Heavy-duty Truck	1.456	0.018	0.011	vehicle-mile
Passenger Car [A]	0.368	0.018	0.013	vehicle-mile
Light-duty Truck [B]	0.501	0.024	0.019	vehicle-mile
Medium- and Heavy-duty Truck	0.296	0.0036	0.0022	ton-mile
Rail	0.026	0.0020	0.0007	ton-mile
Waterborne Craft	0.042	0.0004	0.0027	ton-mile
Aircraft	1.301	0.0000	0.0400	ton-mile

Source:
CO_2, CH_4, and N_2O emissions data for highway vehicles are from Table 2-15 of the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012. Vehicle-miles and passenger-miles data for highway vehicles are from Table VM-1 of the Federal Highway Administration Highway Statistics 2012.
CO_2e emissions data for non-highway vehicles are based on Table A-116 of the U.S. Greenhouse Gas Emissions and Sinks: 1990–2012, which are distributed into CO_2, CH_4, and N_2O emissions based on fuel/vehicle emission factors.
Freight ton-mile data for non-highway vehicles are from Table 1-50 of the Bureau of Transportation Statistics, National Transportation Statistics for 2012.

Notes:
Vehicle-mile factors are appropriate to use when the entire vehicle is dedicated to transporting the reporting company's product. Ton-mile factors are appropriate when the vehicle is shared with products from other companies.
[A] Passenger car: includes passenger cars, minivans, SUVs, and small pickup trucks (vehicles with wheelbase less than 121 inches).
[B] Light-duty truck: includes full-size pickup trucks, full-size vans, and extended-length SUVs (vehicles with wheelbase greater than 121 inches).

Table 9 Global Warming Potentials (GWPs)

Gas	100-year GWP
CO_2	1
CH_4	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-41	92
HFC-125	3,500
HFC-134	1,100
HFC-134a	1,430
HFC-143	353
HFC-143a	4,470
HFC-152	53
HFC-152a	124
HFC-161	12
HFC-227ea	3,220
HFC-236cb	1,340
HFC-236ea	1,370
HFC-236fa	9,810
HFC-245ca	693
HFC-245fa	1,030
HFC-365mfc	794
HFC-43-10mee	1,640
SF_6	22,800
NF_3	17,200
CF_4	7,390
C_2F_6	12,200
C_3F_8	8,830
c-C_4F_8	10,300
C_4F_{10}	8,860
C_5F_{12}	9,160
C_6F_{14}	9,300
$C_{10}F_{18}$	>7,500

Source:
100-year GWPs from IPCC Fourth Assessment Report (AR4), 2007. IPCC AR4 was published in 2007 and is among the most current and comprehensive peer-reviewed assessments of climate change. AR4 provides revised GWPs of several GHGs relative to the values provided in previous assessment reports, following advances in scientific knowledge on the radiative efficiencies and atmospheric lifetimes of these GHGs and of CO_2. Because the GWPs provided in AR4 reflect an improved scientific understanding of the radiative effects of these gases in the atmosphere, the values provided are more appropriate for supporting the overall goal of organizational GHG reporting than the Second Assessment Report (SAR) GWP values previously used in the Emission Factors Hub.
While EPA recognizes that Fifth Assessment Report (AR5) GWPs have been published, in an effort to ensure consistency and comparability of GHG data between EPA's voluntary and non-voluntary GHG reporting programs (e.g. GHG Reporting Program and National Inventory), EPA recommends the use of AR4 GWPs. The United States and other developed countries to the UNFCCC have agreed to submit annual inventories in 2015 and future years to the UNFCCC using GWP values from AR4, which will replace the current use of SAR GWP values. Utilizing AR4 GWPs improves EPA's ability to analyze corporate, national, and sub-national GHG data consistently, enhances communication of GHG information between programs, and gives outside stakeholders a consistent, predictable set of GWPs to avoid confusion and additional burden.

Table 9b GWPs for Blended Refrigerants

ASHRAE #	100-year GWP	Blend Composition
R-401A	16	53% HCFC-22 , 34% HCFC-124 , 13% HFC-152a
R-401B	14	61% HCFC-22 , 28% HCFC-124 , 11% HFC-152a
R-401C	19	33% HCFC-22 , 52% HCFC-124 , 15% HFC-152a
R-402A	2,100	38% HCFC-22 , 6% HFC-125 , 2% propane
R-402B	1,330	6% HCFC-22 , 38% HFC-125 , 2% propane
R-403B	3,444	56% HCFC-22 , 39% PFC-218 , 5% propane
R-404A	3,922	44% HFC-125 , 4% HFC-134a , 52% HFC 143a
R-406A	0	55% HCFC-22 , 41% HCFC-142b , 4% isobutane
R-407A	2,107	20% HFC-32 , 40% HFC-125 , 40% HFC-134a
R-407B	2,804	10% HFC-32 , 70% HFC-125 , 20% HFC-134a
R-407C	1,774	23% HFC-32 , 25% HFC-125 , 52% HFC-134a
R-407D	1,627	15% HFC-32 , 15% HFC-125 , 70% HFC-134a
R-407E	1,552	25% HFC-32 , 15% HFC-125 , 60% HFC-134a
R-408A	2,301	47% HCFC-22 , 7% HFC-125 , 46% HFC 143a
R-409A	0	60% HCFC-22 , 25% HCFC-124 , 15% HCFC-142b
R-410A	2,088	50% HFC-32 , 50% HFC-125
R-410B	2,229	45% HFC-32 , 55% HFC-125
R-411A	14	87.5% HCFC-22 , 11 HFC-152a , 1.5% propylene
R-411B	4	94% HCFC-22 , 3% HFC-152a , 3% propylene
R-413A	2,053	88% HFC-134a , 9% PFC-218 , 3% isobutane
R-414A	0	51% HCFC-22 , 28.5% HCFC-124 , 16.5% HCFC-142b
R-414B	0	5% HCFC-22 , 39% HCFC-124 , 9.5% HCFC-142b
R-417A	2,346	46.6% HFC-125 , 5% HFC-134a , 3.4% butane
R-422A	3,143	85.1% HFC-125 , 11.5% HFC-134a , 3.4% isobutane
R-422D	2,729	65.1% HFC-125 , 31.5% HFC-134a , 3.4% isobutane
R-423A	2,280	47.5% HFC-227ea , 52.5% HFC-134a ,
R-424A	2,440	50.5% HFC-125, 47% HFC-134a, 2.5% butane/pentane
R-426A	1,508	5.1% HFC-125, 93% HFC-134a, 1.9% butane/pentane
R-428A	3,607	77.5% HFC-125 , 2% HFC-143a , 1.9% isobutane
R-434A	3,245	63.2% HFC-125, 16% HFC-134a, 18% HFC-143a, 2.8% isobutane
R-500	32	73.8% CFC-12 , 26.2% HFC-152a , 48.8% HCFC-22
R-502	0	48.8% HCFC-22 , 51.2% CFC-115
R-504	325	48.2% HFC-32 , 51.8% CFC-115
R-507	3,985	5% HFC-125 , 5% HFC143a
R-508A	13,214	39% HFC-23 , 61% PFC-116
R-508B	13,396	46% HFC-23 , 54% PFC-116

Source:
100-year GWPs from IPCC Fourth Assessment Report (AR4), 2007. See the source note to Table 9 for further explanation. GWPs of blended refrigerants are based on their HFC and PFC constituents, which are based on data from http://www.epa.gov/ozone/snap/refrigerants/refblend.html.