

1 Introduction

This report describes methods used to compile the annual publication of U.S. anthropogenic greenhouse gas (GHG) emissions and sinks disaggregated by U.S. state and consistent with the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (national *Inventory* hereafter). By April of each year, the U.S. Environmental Protection Agency (EPA) prepares the official national *Inventory*, presenting time series estimates by gas, source/sink, and sector. The latest annual report includes estimates from 1990–2021 and is available here:

<https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>. This state-level report is complementary publication released annually after the national *Inventory* report.

EPA recognizes that a number of states have compiled or are developing their own state-level GHG inventories on a regular or periodic basis. The state-level inventory data presented here should not be viewed as official data of any state government, and EPA provides users information on where they can find official state-level data from EPA's website here: <https://www.epa.gov/ghgemissions/learn-more-about-official-state-greenhouse-gas-inventories>. In addition, for states where an official inventory is available, EPA's GHG Data Explorer provides links along with the published state-level data so that when users query information for a particular state, the link to view the official state inventory will be shown. States themselves may find this information useful to facilitate comparisons, for quality assurance and quality control (QA/QC), to supplement and complement existing state efforts, or to serve as official estimates, depending on their own circumstances and policy needs.

The state-level estimates described in this document are consistent with the national *Inventory*, meaning they:

- Adhere to international standards, including the Intergovernmental Panel on Climate Changes (IPCC) Guidelines and United Nations Framework Convention on Climate Change (UNFCCC) transparency reporting system. The emissions and removals presented in this report are organized by source and sink categories within IPCC sectors (energy; industrial processes and product use [IPPU]; agriculture, land use, land-use change, and forestry [LULUCF]; and waste) and their respective source and sink categories.
- Are based on the same methodologies as the national *Inventory* and reflect the latest methodological improvements in the national *Inventory*, including the use of Greenhouse Gas Reporting Program (GHGRP) data.
- Cover the complete time series consistent with the national *Inventory*, starting with 1990 through the latest national *Inventory* year (i.e., 2021).
- Cover all anthropogenic sources and sinks, and all seven gases (carbon dioxide [CO₂], methane [CH₄], nitrous oxide [N₂O], hydrofluorocarbons [HFCs], perfluorocarbons [PFCs], sulfur hexafluoride [SF₆], and nitrogen trifluoride [NF₃]). The completeness and geographic disaggregation of the report are consistent with the national *Inventory*, meaning in addition to estimates for states, the methods also address emissions and removals occurring in the District of Columbia, U.S. territories, and tribal lands.
- Use estimates that were compiled to avoid double counting or gaps in emissions coverage between states, ensuring that state totals, when summed, will equal totals in the national *Inventory*. This is important for those looking for consistent, comparable, and complete state data for analyses and other purposes where double counting or omissions would be problematic.

This report's chapters are organized by UNFCCC reporting sectors¹ and their respective source and sink categories. Domestic and international users alike will recognize this format given its long-established use by

¹ The international reporting guidelines under the UNFCCC require reporting of GHG emissions and removals across five sectors: energy, IPPU, agriculture, LULUCF, and waste. Note that while the UNFCCC reporting guidelines require using methods from the 2006 IPCC Guidelines for estimating GHG emissions and removals, they require separate, rather than combined, reporting of emissions and sinks from the agriculture, forestry, and other land use sector as presented in the IPCC guidelines.

countries for UNFCCC reporting. The chapter and category section titles all include a reference to the corresponding section in the national *Inventory* report (NIR), such as NIR Section 3.1., to facilitate understanding national inventory methods in relation to approaches applied to allocate national emissions to the state level. For each category, we recommend reading this report in conjunction with the referenced national *Inventory* sections. Each category section within a chapter includes a background discussion, a description of methods/approaches, and a discussion of planned improvements. The background includes a brief overview of the source or sink category consistent with the national *Inventory*. The methods section includes the approach to develop state-level estimates and the gases covered. The planned improvements indicate areas for improvement identified during this first effort to disaggregate state-level emissions and sinks.

1.1 Areas Where Differences Between State GHG Inventories and the EPA State-Level Estimates May Occur

EPA recognizes that there will be differences between EPA's state-level estimates and some inventory estimates developed independently by individual state governments. Inventories compiled by states may differ for several reasons and differences do not necessarily mean that one set of estimates is more accurate, or "correct." EPA has strived to ensure the coverage, methodological, and accounting approaches are clearly described so users can understand differences with how states may compile their inventories. The results should be viewed as complementary and supplement existing state data. Differences between EPA and official state estimates include:

- **Organization of sectors.** EPA has organized estimates by sector and their respective source and sink categories consistent with the national *Inventory* and international reporting guidelines. Standardization of sectors in international reporting allows countries to compare data and supports cooperation on climate action. States may use alternate organization of data for presenting emissions and sinks, such as economic sectors, rather than IPCC sectors. Some states may use IPCC sectors as the basis of their inventory, but allocate some categories differently across sectors, such as reporting some IPPU categories in the energy sector (e.g., SF₆ from electrical transmission and distribution). Comparability also depends on similar coverage. The completeness and geographic disaggregation of the estimates are consistent with the national *Inventory*, meaning in addition to estimates for states, the methods also address emissions and removals occurring in the District of Columbia, U.S. territories, and tribal lands.
- **Methods and data.** In some cases, EPA may be using different methodologies, activity data, and emissions factors, or may have access to the latest facility-level information through EPA's Greenhouse Gas Reporting Program (GHGRP). EPA used as a basis, or starting point, either the same methods or methods based on those used to compile the national-level estimates. States may use the same methods but use different sources of activity data.
- **Accounting approaches.** In other cases, states may have adopted different accounting decisions that differ from those adopted by the IPCC and UNFCCC (e.g., use of different category definitions and emission scopes consistent with state laws and regulations). For example, EPA's approach is to focus on emissions that occur within geographic state boundaries ("Scope 1"), whereas some states include emissions that are caused by activity within their borders but which actually occur in other states ("Scope 2 or 3"), or they use consumption-based accounting approaches. For example, some states include emissions from imported electricity, or electricity production that occurs outside state boundaries. EPA's use of geographic state boundaries to allocate emissions is consistent with the methodological framework in the IPCC guidelines.² Differences in accounting approaches also include differences in the approach to

² Per the 2006 IPCC Guidelines, national inventories include GHG emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction with some minor exceptions. For example, one exception is "CO₂ emissions from road vehicles should be attributed to the country where the fuel is sold to the end user." See Volume 1, Chapter

estimating transportation, cross-border aviation and marine emissions, or treatment of biogenic CO₂. For example, EPA does not include biogenic CO₂ emissions in state energy sector totals because, in accordance with IPCC methodological guidelines, CO₂ emissions and removals due to the harvesting, combustion, and growth of biomass are included in the carbon stock (C stock) changes of the relevant land use category of the agriculture and LULUCF sectors, where the biomass originates, and including these emissions in energy sector totals would result in double counting.³ Users of state GHG data should take care to review and understand differences in accounting approaches to ensure that any comparisons of estimates are based on an equivalent or an apples to apples comparison of estimates.

- **Time series.** EPA has developed state-level estimates for 1990–2021 consistent with the national *Inventory* published in April 2023 and current UNFCCC reporting requirements. States may estimate emissions and sinks over a different time period based on state goals, designation of different base years, legislation, and available state data. Some states may not estimate back to 1990 and include only more recent years. Other states may have previously published estimates for earlier years, but not recalculated or otherwise updated these estimates in more recent publications despite changes in methods, activity data, or emissions factors. Similarly, new emissions sources may be added in recent years but not estimated for more distant years.
- **Global warming potentials (GWPs).** States may use different metrics for CO₂ equivalency of non-CO₂ gases, such as different values for GWPs. Consistent with the national *Inventory*, in this report EPA is using 100-year GWPs from IPCC’s Fifth Assessment Report (AR5) to calculate CO₂ equivalency of non-CO₂ emissions, as required in reporting annual inventories to the UNFCCC. EPA shifted to using 100-year GWPs from AR5 in 2023. Recent decisions⁴ under the UNFCCC require members of the Conference of Parties to use 100-year GWP values from AR5 for calculating CO₂-equivalents in their national reporting (IPCC 2013) by the end of 2024. This requirement reflects updated science and ensures that national GHG inventories reported by all nations are comparable.

1.2 Institutional Arrangements for Compiling State-Level Inventory Estimates

In preparing the state-level inventory, EPA took advantage of existing data arrangements used to compile the national *Inventory* (see Chapter 1.2 of the national *Inventory*). EPA acknowledges the additional contributions from the U.S. Department of Agriculture’s U.S. Forest Service (USDA-USFS) and National Oceanic and Atmospheric Administration (NOAA). USDA-USFS has ongoing efforts to prepare state-level data⁵ to track emissions and sinks from land use and land use change in forested lands and settlement lands. NOAA has compiled the state-level emissions and removals from coastal wetlands. EPA also acknowledges additional effort from USDA’s National Agricultural Statistics Service (NASS) and Office of Chief Economist (OCE) for providing state-level data on energy use in agriculture and from the Department of Energy’s Energy Information Administration (EIA) for providing state-level energy use data. Finally, EPA acknowledges contributions and investments from USDA-OCE that will facilitate addressing some of the planned improvements outlined in Chapters 4 and 5 of this report.

8, Section 8.2.1, on Coverage, available online at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_8_Ch8_Reporting_Guidance.pdf.

³ See Q2-10 of Frequently Asked Questions on general guidance and other inventory issues: <https://www.ipcc-nggip.iges.or.jp/faq/faq.html>.

⁴ See paragraphs 1 and 2 of the decision on common metrics adopted at the 27th UNFCCC Conference of Parties (COP27), available online at https://unfccc.int/sites/default/files/resource/cp2022_10a01_adv.pdf

⁵ https://www.fs.fed.us/nrs/pubs/download/ru_fs307_Appendix2.pdf.

EPA also collects GHG emissions data from individual facilities and suppliers of certain fossil fuels and industrial gases through its GHGRP.⁶ The GHGRP does not provide full economywide coverage of total annual U.S. GHG emissions and sinks (e.g., the GHGRP does not collect data on emissions from the agricultural, land use, and forestry sectors), but it is an important input to the calculations of state-level estimates in the national *Inventory*. In general, the threshold for reporting is 25,000 metric tons or more of CO₂ equivalent per year. Facilities in most source categories subject to GHGRP began reporting for the reporting year (RY) 2010, while additional types of industrial operations began reporting for RY 2011. When incorporating these data from GHGRP, consistent with the national *Inventory*, EPA considers good practice guidance from the 2019 Refinement to the 2006 IPCC Guidelines (Volume 1, Chapter 2)⁷ and IPCC's Technical Bulletin on Use of Facility-Specific Data in National GHG Inventories⁸ to ensure, completeness, time series consistency, and transparency in state-level methods and associated estimates.

Data presented in this state-level inventory report and EPA's GHGRP are complementary. As discussed across this report, in addition to annual emissions information, the GHGRP also provides other annual information such as activity data and emissions factors that can improve and refine state-level trends over time. More information on the relationship between GHGRP and the national *Inventory* is available online at <https://www.epa.gov/ghgreporting/greenhouse-gas-reporting-program-and-us-inventory-greenhouse-gas-emissions-and-sinks>.

1.3 Methods Overview

In developing the state-level estimates consistent with the national *Inventory*, EPA used as a basis, or starting point, the same methods or methods based on those used to compile the national-level estimates. From this starting point, there were three different approaches taken to arrive at state-level estimates:

- **Approach 1.** Estimates were built by applying national methods directly to more geographically disaggregated data (at state or finer level). For example, estimates of forest land remaining forest land and of lands converted to forest land are built from existing data sets that already disaggregate to the state level (see Section 5.1.1). Also, portions of fossil fuel combustion emissions were based on the same approach as the national estimates using state disaggregated energy consumption data (see Section 2.1.1).
- **Approach 2.** Estimates were disaggregated from national-level estimates using geographic proxies or other indicators (e.g., population, production capacity, GHGRP). This approach was used for categories where the type of state data used in Approach 1 were not available or were incomplete. For example, Approach 2 is used to estimate state-level emissions from other process uses of carbonates (see Section 3.1.4) where state-level population is used as a proxy to allocate national emissions. A key factor in Approach 2 is how well emissions correlate with proxies, and where multiple options exist, how to choose among them.
- **Hybrid approach.** Under this approach, estimates used a combination of Approach 1 and Approach 2 methods over the time series because data availability limited the use of Approach 1 for all years of the time series. For example, some estimates may use EPA's GHGRP, which began collecting data in 2010, as a basis for national- and state-level estimates. For these categories, EPA uses Approach 1 for 2010–2021 and uses Approach 2 for earlier years of the time series to arrive at state-level estimates, using IPCC guidance to ensure consistency over the time series to the extent possible. For example, the Hybrid

⁶ <https://www.epa.gov/ghgreporting>

⁷ https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/1_Volume1/19R_V1_Ch02_DataCollection.pdf

⁸ https://www.ipcc-nggip.iges.or.jp/public/tb/TFI_Technical_Bulletin_1.pdf

approach is used to estimate state-level CO₂ and PFC emissions from aluminum production (see Section 3.3.3).

Across this report, in addition to a sector-level summary, under each category, EPA has indicated the approach used to disaggregate national estimates to the state level. Where appropriate for explaining methods used under Approach 2 or the Hybrid approach, EPA has included equations to enhance understanding of the implementation of disaggregation methods. EPA has also included data appendices to provide underlying data to estimate emissions and sinks.

1.4 Summary of Updates Since Previous Report

Each year, many emission and sink estimates in the national *Inventory* are recalculated and revised, as efforts are made to improve the estimates through the use of better methods and/or data with the goal of improving inventory quality and reducing uncertainties, including the transparency, completeness, consistency, and overall usefulness of the report. The same is the case with state-level estimates where updates were made to improve inventory quality. In general, when methodological changes have been implemented, the previous national *Inventory's* time series (i.e., 1990–2020) was recalculated to reflect the change. Note that the most common reason for recalculating national GHG emission estimates is to update recent historical activity data. Changes in historical data are generally the result of changes in statistical data supplied by other U.S. government agencies, and do not necessarily impact the entire time series.

A summary of methodological changes and historical data updates made to the state-level data is presented below by category. Table 1-1 notes whether changes are due to refinements in the national *Inventory* methods and data, including new categories, and/or due to an update that refined the approach and data used to disaggregate national estimates to the state level. Note that when category-level changes in absolute state-level emissions or removals for a state between this version and the previous state report are due to recalculations and improvements implemented in the national *Inventory*, changes are indicated only in the national-level column in Table 1-1 below, as the approach to disaggregation of the updated national estimates to the state level remains unchanged. Categories not listed had no changes for either the national or state-level estimates. See the recalculations sections of each category for more detail on the updates within this report.

Table 1-1. Category Estimates Updated Since Release of Previous Inventory by U.S. State

IPCC Sector	Category	Changes to Inventory (i.e., Refined Method/Data or New Category)	
		National-Level	State-Level
E	Fuel Combustion	●	●
E	Non-Energy Use of Fuels	●	●
E	Oil and Gas Systems (revision of methodology to use basin level data for certain segments), Abandoned Oil and Gas Wells	●	●
I	Glass Production	●	
I	Other Process Uses of Carbonates	●	●
I	CO ₂ Emissions from CO ₂ Consumption		●
I	Ammonia Production	●	
I	CO ₂ from Urea Use		●
I	Adipic Acid	●	●
I	CO ₂ from Carbide Production		●
I	Titanium Dioxide Production		●
I	Petrochemicals		●
I	Phosphoric Acid Production		●

IPCC Sector	Category	Changes to Inventory (i.e., Refined Method/Data or New Category)	
		National-Level	State-Level
I	Iron and Steel Production	●	
I	Aluminum Production	●	
I	Magnesium Production	●	●
I	Lead Production		●
I	Zinc Production	●	
I	Electronics Industry	●	●
I	ODS Substitutes	●	
I	Electrical Transmission and Distribution	●	●
I	N ₂ O from Product Use		●
A	Enteric Fermentation	●	
A	Manure Management	●	
A	Agricultural Soil Management	●	
A	Liming	●	
A	Urea Fertilization	●	
L	Forest Land Remaining Forest Land	●	
L	Land Converted to Forest Land	●	
L	Land Converted to Cropland	●	
L	Grassland Remaining Grassland	●	
L	Land Converted to Grassland	●	
L	Wetlands Remaining Wetlands	●	●
L	Land Converted to Wetlands	●	●
L	Settlements Remaining Settlements (subcategory N ₂ O from soils, subcategory landfilled yard trimmings and food scraps)	●	●
L	Land Converted to Settlements	●	
W	Landfills	●	
W	Composting	●	
W	Anerobic Digestion at Biogas Facilities	●	
W	Wastewater Treatment and Discharge	●	●

E = Energy Sector; I = Industrial Processes and Product Use; A = Agriculture; L = Land Use Change, Land Use Change and Forestry; W = Waste

1.5 QA/QC Procedures

In disaggregating emissions and sinks from the national *Inventory*, EPA implemented QC procedures during the compilation process to ensure quality, transparency, and credibility of the state GHG data. EPA implemented general QC procedures adapted from the existing QA/QC plan⁹ for the national *Inventory* to ensure that data processing and application of methods could easily identify and correct errors (i.e., data/unit transcription, computation, and trend checks). EPA also implemented additional category-specific QC procedures to assess disaggregation approaches (e.g., comparisons with other data such as available state GHG inventories) to further review methods and resulting estimates, including comparing category estimates to available state GHG inventories and comparing the sum of state estimates to national estimates. When additional category-specific QC procedures were implemented, the procedure and findings are discussed in the respective category section.

⁹ See the introduction (Section 1.6) and Annex 8 of the national *Inventory* for more information on the QA/QC plan available online at: <https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019>.

EPA also implemented QA procedures outlined by EPA and IPCC as QA good practices (i.e., external review by experts not directly involved in compiling the data). EPA conducted a peer review in fall 2021, and an annual 30-day state expert review in summer 2023. Both reviews are described further below. The QA/QC findings also informed the overall improvement planning, and specific improvements are noted in the planned improvements sections of respective categories.

1.5.1 Peer Review

The methodology report and the resulting state-level estimates for the 1990–2019 data were independently peer reviewed from September 17 to November 1, 2021. Seventeen external experts participated in a process independently coordinated by RTI International and an EPA peer-review coordinator.

EPA gratefully acknowledges all the peer reviewers for their useful comments. The peer review report and responses from EPA are available online here: <https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals>. The information and views expressed in this report do not necessarily represent those of the peer reviewers, who also bear no responsibility for any remaining errors or omissions. Details describing this review can be found below. Peer review of the report followed the procedures in EPA’s Peer Review Handbook, 4th Edition (EPA/100/B-15/001) for reports that do not provide influential scientific information.

The review was managed by a contractor under the direction of a designated EPA peer review leader, who coordinated the preparation of a peer review plan, the scope of work for the review contract, and the charge for the reviewers. The peer review leader played no role in producing the draft report. Each sectoral reviewer was charged with reviewing the Introduction, the sector or subsector of the report relevant to their expertise, resulting estimates, and data appendices. Peer reviewers were charged with making specific comments and edits as well as providing a written response to a set of general and category-specific charge questions. The EPA author team then responded to and addressed all comments from the peer reviewers in a written summary and revised the report accordingly.

1.5.2 State Expert Review

Technical staff from each state (e.g., environmental agencies, other state agencies, institutions) were provided with an opportunity to review the draft data and a draft of this methodology report from July 17–August 16, 2023. The methodology report and state-level estimates were shared with state experts from all 50 U.S. states and the District of Columbia for review.

EPA gratefully acknowledges all the state experts for their review. EPA asked state experts for feedback on this methodology report, its data appendices, and the resulting estimates.

No additional technical comments were received on the draft report. Responses to comments from the previous review are available at <https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals>. See category-specific planned improvement discussions throughout this report reflecting updates planned for future publications of these data.

1.6 Uncertainty

EPA has not assessed state-specific or category-level quantitative uncertainties for the activity data and other parameters used to estimate state-level emissions and removals for this current publication but has included

qualitative information on how uncertainties compare to those assessed quantitatively for each category in the national *Inventory*.¹⁰

The uncertainties of state-level emissions estimates are generally expected to be comparable to or higher than the uncertainties of national-level emissions estimates for two reasons. First, where emissions are estimated at the national level and then allocated to states based on proxy or surrogate data and indicators other than those used to estimate emissions (i.e., where Approach 2 is used), uncertainties in the relationship between the allocation indicator and the emissions increase the uncertainty of the allocation. For example, where total U.S. production is multiplied by an emissions factor to obtain total national-level emissions, but production capacity rather than production is used to allocate the U.S. emissions to facilities and states, variation in each facility's capacity utilization will not be reflected in the estimates, increasing their uncertainty. Second, for some categories where state-level emissions are estimated using the same facility-based methods as are used for national-level emissions (i.e., where Approach 1 is used), state-level uncertainties will generally be higher than national-level uncertainties (in percentage terms), assuming the uncertainties in the estimates for each facility and state are independent of each other. For example, EPA estimates the uncertainties in emissions from aluminum production at individual smelters to be +6/–6%, +16/–16%, and +20/–20% for CO₂, perfluoromethane and perfluoroethane emissions, respectively. When propagated to the national level across the seven smelters that operated in 2021, these uncertainties decline to –2%/+3% for CO₂ and +8/–8% for PFCs. Since the states with aluminum production each have just one to two smelters, the uncertainties in the state-level emissions will be closer to the uncertainties in the emissions for individual smelters than to the uncertainties in the national-level emissions.

For more information on uncertainties with national-level GHG estimates, see Section 1.7 of the Introduction chapter to the national *Inventory*. Category-specific uncertainties for national estimates are included in the category-specific methodological discussions across the national *Inventory* report.

1.7 Planned Improvements

Across this report, per EPA's QC and feedback from the previous peer and state reviews, EPA has outlined areas for improving future annual publications of these data at the category level across the report. Based on feedback, EPA continues to prioritize the following cross-cutting improvements for future annual publications of these data:

- Finalize state-level key category analyses consistent with IPCC guidance and international reporting guidelines to help identify categories that are more significant at the state level and publish in fall of 2023.
- Disaggregate estimates further for U.S. territories (in GHG Inventory Data Explorer) and tribal lands, where feasible.
- Publish additional state-level activity data/factors underlying estimates where feasible and not previously included.

¹⁰ Within the forest land remaining forest land and lands converted to forest land categories, USFS has quantified uncertainties for state-level estimates for net CO₂ flux from forest ecosystem carbon pools and non-CO₂ emissions from forest fires that are the basis for the estimates also in the national *Inventory*. The quantified uncertainties are available in the USDA-USFS Resource Bulletin WO–101 (Domke et al., 2023), available at: <https://www.fs.usda.gov/research/treesearch/66035>.

1.8 References

IPCC (Intergovernmental Panel on Climate Change) (2013) *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. T.F. Stocker, D. Qin, G.-K. Plattner, M.B. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley (eds.). Cambridge University Press.