U.S. Greenhouse Gas Emissions

Identification

1. Indicator Description

This indicator describes emissions of greenhouse gases (GHGs) in the United States and its territories between 1990 and 2014. It reports emissions of GHGs according to their global warming potential, a measure of how much a given amount of the GHG is estimated to contribute to global warming over a selected period of time. For the purposes of comparison, global warming potential values are given in relation to carbon dioxide (CO_2) and are expressed in terms of CO_2 equivalents. This indicator is highly relevant to climate change because greenhouse gases from human activities are the primary driver of observed climate change since the mid-20th century (IPCC, 2013).

Components of this indicator include:

- U.S. GHG emissions by gas (Figure 1).
- U.S. GHG emissions and sinks by economic sector (Figure 2).
- U.S. GHG emissions per capita and per dollar of GDP (Figure 3).

2. Revision History

April 2010:	Indicator published.
December 2012:	Updated indicator with data through 2010.
August 2013:	Updated indicator on EPA's website with data through 2011.
May 2014:	Updated indicator with data through 2012.
June 2015:	Updated indicator on EPA's website with data through 2013.
August 2016:	Updated indicator with data through 2014.

Data Sources

3. Data Sources

This indicator uses data and analysis from EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA, 2016), an assessment of the anthropogenic sources and sinks of GHGs for the United States and its territories for the period from 1990 to 2014.

4. Data Availability

The complete U.S. GHG inventory is published annually, and the version used to prepare this indicator is publicly available at: www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html (U.S. EPA, 2016). The figures in this indicator are taken from the following figures and tables in the inventory report:

- Figure 1 (emissions by gas): Figure ES-1/Table ES-2/Table 2-1.

- Figure 2 (emissions by economic sector): Figure ES-13/Table ES-6/Table 2-10.
- Figure 3 (emissions per capita and per dollar gross domestic product [GDP]): Figure ES-15/Table ES-8/Table 2-14.

The inventory report does not present data for the years 1991–2004 or 2006–2009 due to space constraints; however, data for these years can be obtained by downloading the complete supporting tables or by contacting EPA's Climate Change Division (www3.epa.gov/climatechange/contactus.html).

Figure 3 includes trends in population and real GDP. EPA obtained publicly available population data from the U.S. Census Bureau's International Data Base at: www.census.gov/population/international/. EPA obtained GDP data from the U.S. Department of Commerce, Bureau of Economic Analysis. These data are publicly available from the Bureau of Economic Analysis website at: www.bea.gov/national/index.htm#gdp.

Methodology

5. Data Collection

This indicator uses data directly from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA, 2016). The inventory presents estimates of emissions derived from direct measurements, aggregated national statistics, and validated models. Specifically, this indicator focuses on the long-lived greenhouse gases currently covered by agreements under the United Nations Framework Convention on Climate Change (UNFCCC). These compounds are CO_2, methane (CH_4), nitrous oxide (N_2O), selected hydrofluorocarbons (HFCs), selected perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

The emissions and source activity data used to derive the emissions estimates are described thoroughly in EPA's inventory report. The scientifically approved methods can be found in the Intergovernmental Panel on Climate Change's (IPCC's) GHG inventory guidelines (www.ipcc-nggip.iges.or.jp/public/2006gl/index.html) (IPCC, 2006) and in IPCC's *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (www.ipcc-nggip.iges.or.jp/public/gp/english) (IPCC, 2000). More discussion of the sampling and data sources associated with the inventory can be found at: www3.epa.gov/climatechange/ghgemissions.

The U.S. GHG inventory provides a thorough assessment of the anthropogenic emissions by sources and removals by sinks of GHGs for the United States from 1990 to 2014. Although the inventory is intended to be comprehensive, certain identified sources and sinks have been excluded from the estimates (e.g., CO_2 from burning in coal deposits and waste piles, CO_2 from natural gas processing). Sources are excluded from the inventory for various reasons, including data limitations or an incomplete understanding of the emissions process. The United States is continually working to improve understanding of such sources and seeking to find the data required to estimate related emissions. As such improvements are made, new emissions sources are quantified and included in the inventory. For a complete list of excluded sources, see Annex 5 of the U.S. GHG inventory report (www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html).

Figure 3 of this indicator compares emissions trends with trends in population and U.S. GDP. Population data were collected by the U.S. Census Bureau. For this indicator, EPA used midyear estimates of the

total U.S. population. GDP data were collected by the U.S. Department of Commerce, Bureau of Economic Analysis. For this indicator, EPA used real GDP in chained 2009 dollars, which means the numbers have been adjusted for inflation. See: www.census.gov/population/international for the methods used to determine midyear population estimates for the United States. See: www.bea.gov/methodologies/index.htm#national_meth for the methods used to determine GDP.

6. Indicator Derivation

The U.S. GHG inventory was constructed following scientific methods described in the Intergovernmental Panel on Climate Change's (IPCC's) *Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006) and in IPCC's *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). EPA's annual inventory reports and IPCC's inventory development guidelines have been extensively peer reviewed and are widely viewed as providing scientifically sound representations of GHG emissions.

U.S. EPA (2016) provides a complete description of methods and data sources that allowed EPA to calculate GHG emissions for the various industrial sectors and source categories. Further information on the inventory design can be obtained by contacting EPA's Climate Change Division (www3.epa.gov/climatechange/contactus.html).

The inventory covers U.S. GHG data for the years 1990 to 2014, and no attempt has been made to incorporate other locations or to project data forward or backward from this time window. Some extrapolation and interpolation were needed to develop comprehensive estimates of emissions for a few sectors and sink categories, but in most cases, observations and estimates from the year in question were sufficient to generate the necessary data.

This indicator reports trends exactly as they appear in EPA's GHG inventory (U.S. EPA, 2016). The indicator presents emissions data in units of million metric tons of CO_2 equivalents, the conventional unit used in GHG inventories prepared worldwide, because it adjusts for the various global warming potentials (GWPs) of different gases. The indicator now uses the 100-year GWPs documented in the IPCC's Fourth Assessment Report (AR4) (IPCC, 2007). EPA is required to use these GWPs for the development of the GHG inventory to comply with international reporting standards under the UNFCCC. This requirement ensures that current estimates of aggregate greenhouse gas emissions for 1990 to 2014 are consistent with estimates developed prior to the publication of the IPCC's Fifth Assessment Report (AR5) in 2013. Annex 6.1 of the U.S. GHG inventory includes extensive information on GWPs and how they relate to emissions estimates (U.S. EPA, 2016).

Figure 1. U.S. Greenhouse Gas Emissions by Gas, 1990–2014

EPA plotted total emissions for each gas, not including the influence of sinks, which would be difficult to interpret in a breakdown by gas. EPA combined the emissions of HFCs, PFCs, SF_6, and NF_3 into a single category so the magnitude of these emissions would be visible in the graph.

Figure 2. U.S. Greenhouse Gas Emissions and Sinks by Economic Sector, 1990–2014

EPA converted a line graph in the original inventory report (U.S. EPA, 2016) into a stacked area graph showing emissions by economic sector. U.S. territories are treated as a separate sector in the inventory report, and because territories are not an economic sector in the truest sense of the word, they have

been excluded from this part of the indicator. Unlike Figure 1, Figure 2 includes sinks below the x-axis. The section below the x-axis represents the entire contribution of the land use, land-use change, and forestry sector, which includes a relatively small amount of emissions that is outweighed by a much larger sink.

Figure 3. U.S. Greenhouse Gas Emissions per Capita and per Dollar of GDP, 1990–2014

EPA determined emissions per capita and emissions per unit of real GDP using simple division. In order to show all four trends (population, GDP, emissions per capita, and emissions per unit GDP) on the same scale, EPA normalized each trend to an index value of 100 for the year 1990.

7. Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) have always been an integral part of the U.S. national system for inventory development. EPA and its partner agencies have implemented a systematic approach to QA/QC for the annual U.S. GHG inventory, following procedures that have been formalized in accordance with a QA/QC plan and the UNFCCC reporting guidelines. Those interested in documentation of the various QA/QC procedures should send such queries to EPA's Climate Change Division (www3.epa.gov/climatechange/contactus.html).

Analysis

8. Comparability Over Time and Space

The U.S. GHG emissions data presented in this indicator are comparable over time and space, and the purpose of the inventory is to allow tracking of annual emissions over time. The emissions trend is defined in the inventory as the percentage change in emissions (or removal) estimated for the current year, relative to the emissions (or removal) estimated for the base year (i.e., 1990) inventory estimates. In addition to the estimates of uncertainty associated with the current year's emissions estimates, Annex 7 of the inventory report also presents quantitative estimates of trend uncertainty.

9. Data Limitations

Factors that may impact the confidence, application, or conclusions drawn from this indicator are as follows:

1. This indicator does not yet include emissions of GHGs or other radiatively important substances that are not explicitly covered by the UNFCCC and its subsidiary protocol. Thus, it excludes gases such as those controlled by the Montreal Protocol and its Amendments, including chlorofluorocarbons and hydrochlorofluorocarbons. Although the United States reports the emissions of these substances as part of the U.S. GHG inventory (see Annex 6.2 of U.S. EPA [2016]), the origin of the estimates is fundamentally different from those of the other GHGs, and therefore these emissions cannot be compared directly with the other emissions discussed in this indicator.

2. This indicator does not include aerosols and other emissions that affect radiative forcing and that are not well-mixed in the atmosphere, such as sulfate, ammonia, black carbon, and organic

carbon. Emissions of these compounds are highly uncertain and have qualitatively different effects from the six types of emissions in this indicator.

3. This indicator does not include emissions of other compounds—such as carbon monoxide, nitrogen oxides, non-methane volatile organic compounds, and substances that deplete the stratospheric ozone layer—that indirectly affect the Earth's radiative balance (for example, by altering GHG concentrations, changing the reflectivity of clouds, or changing the distribution of heat fluxes).

4. The U.S. GHG inventory does not account for "natural" emissions of GHGs from sources such as wetlands, tundra soils, termites, and volcanoes. These excluded sources are discussed in Annex 5 of the U.S. GHG inventory (U.S. EPA, 2016). The "land use," "land-use change," and "forestry" categories in U.S. EPA (2016) do include emissions from changes in the forest inventory due to fires, harvesting, and other activities, as well as emissions from agricultural soils.

10. Sources of Uncertainty

Some estimates, such as those for CO_2 emissions from energy-related activities and cement processing, are considered to have low uncertainties. For some other categories of emissions, however, lack of data or an incomplete understanding of how emissions are generated increases the uncertainty of the estimates presented.

Recognizing the benefit of conducting an uncertainty analysis, the UNFCCC reporting guidelines follow the recommendations of IPCC (2000) and require that countries provide single point uncertainty estimates for many sources and sink categories. The U.S. GHG inventory (U.S. EPA, 2016) provides a qualitative discussion of uncertainty for all sources and sink categories, including specific factors affecting the uncertainty surrounding the estimates. Most sources also have a quantitative uncertainty assessment in accordance with the new UNFCCC reporting guidelines. Thorough discussion of these points can be found in U.S. EPA (2016). Annex 7 of the inventory publication is devoted entirely to uncertainty in the inventory estimates.

For a general idea of the degree of uncertainty in emissions estimates, WRI (2015) provides the following information: "According to the most recent IPCC report (IPCC, 2014), estimated uncertainty for global CO_2 emissions from fossil fuels is relatively low, about 8%. For non-CO_2 GHG emissions, CH_4 and F-gases have relatively 'intermediate' uncertainties of around 20%, while N_2O has a higher uncertainty of around 60%. CO_2 emissions from land-use change and forestry have very large uncertainties of 50–75%. In total, when combining these uncertainties, estimates of global total GHG emissions have an uncertainty of around 10%."

Overall, these sources of uncertainty are not expected to have a considerable impact on this indicator's conclusions. Even considering the uncertainties of omitted sources and lack of precision in known and estimated sources, this indicator provides a generally accurate picture of aggregate trends in GHG emissions over time, and hence the overall conclusions inferred from the data are solid. The U.S. GHG inventory represents the most comprehensive and reliable data set available to characterize GHG emissions in the United States.

11. Sources of Variability

Within each sector (e.g., electricity generation), GHG emissions can vary considerably across the individual point sources, and many factors contribute to this variability (e.g., different production levels, fuel type, air pollution controls). EPA's inventory methods account for this variability among individual emissions sources.

12. Statistical/Trend Analysis

This indicator presents a time series of national emissions estimates. No special statistical techniques or analyses were used to characterize the long-term trends or their statistical significance.

References

IPCC (Intergovernmental Panel on Climate Change). 2000. Good practice guidance and uncertainty management in national greenhouse gas inventories. www.ipcc-nggip.iges.or.jp/public/gp/english.

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