# Direct Emissions from Fluorinated Chemicals (Including HCFC-22) Production

All emissions presented here are as of 9/1/2013 and exclude biogenic $CO_2$. All GHG emissions data displayed in units of carbon dioxide equivalent ($CO_2e$) reflect the global warming potential (GWP) values from IPCC AR4.

## Highlights

- Emissions from Fluorinated Gas Production increased by six percent from 2011 to 2012, to 7.4 million metric tons $CO_2e$ (MMT $CO_2e$).
- Emissions from HCFC-22 Production and HFC-23 Destruction decreased by 37% from 2011 to 2012, to 4.3 MMT $CO_2e$. One facility was responsible for 81% of this reduction.
- The observed decreases in emissions from HCFC-22 Production and HFC-23 Destruction continue a long-term trend established under an EPA voluntary emission reduction program; emissions from HCFC-22 Production and HFC-23 Destruction have decreased by 88% since 1990 under that program.
- Due to the high global warming potentials of fluorinated GHGs, the per-facility emissions from this sector are large, averaging 0.73 MMT $CO_2e$ per facility, nearly double the GHGRP-wide average.

## About this Sector

The Fluorinated Chemicals Production Sector comprises facilities that produce fluorinated gases. Facilities that produce fluorinated gases must report GHG emissions under one of two source categories: (1) fluorinated gas production (excluding processes that generate HFC-23 during the production of HCFC-22) and (2) HCFC-22 production and HFC-23 destruction.

Because fluorinated GHGs often have global warming potentials (GWPs) in the thousands, emissions that are relatively small in mass of a chemical can be large in terms of $CO_2e$.

Fluorinated gas production consists of processes that produce a fluorinated gas (including HFCs, PFCs, $SF_6$, $NF_3$, HFEs, CFCs, and HCFCs) from any raw material or feedstock chemical, except for processes that generate HFC-23 during the production of HCFC-22. Fluorinated gases are manufactured for use as refrigerants, foam blowing agents, insulators in electrical equipment, feed-stocks for manufacturing synthetic polymers, and for a variety of other applications. These fluorinated GHGs may be products, by-products, or feed-stocks for the process, and they may be emitted from process vents, equipment leaks, container filling (including container evacuation prior to refilling), or air pollution control devices. Hereafter, emissions from these processes may be referred to as Subpart L emissions.

HCFC-22 production and HFC-23 destruction consists of (1) processes that produce HCFC-22 from chloroform and hydrogen fluoride, and (2) HFC-23 destruction processes, whether the destruction process is located at the HCFC production facility or not. The GHG emissions reported are emissions of HFC-23 generated during the production of HCFC-22. HFC-23 is a potent GHG that is generated as a by-product during the manufacture of HCFC-22, and is either vented to the atmosphere, captured for use in a limited number of applications, or destroyed. HFC-23 is also emitted from thermal oxidizers during the destruction of HFC-23. Hereafter, emissions from these processes may be referred to as Subpart O emissions.

HCFC-22 is primarily employed in refrigeration and air conditioning systems and as a chemical feedstock for manufacturing synthetic polymers. HCFC-22 is an ozone-depleting substance (ODS)

that is regulated under the Clean Air Act and the Montreal Protocol. Production of HCFC-22 for non-feedstock uses is scheduled to be phased out completely by 2020. However, production of HCFC-22 for use as a feedstock is allowed to continue indefinitely. Together, these two trends are expected to result in a decline in U.S. HCFC-22 production through 2020, followed by a gradual increase.[1]

## Who Reports?

In total, 16 facilities in the Fluorinated Chemicals Production Sector reported in 2012. Total reported emissions were 11.7 MMT $CO_2e$. In 2012, the Fluorinated Chemicals Production Sector represented 0.2% of the facilities reporting direct emissions to the GHGRP and about 0.4% of total U.S. GHG emissions.[2]

**Table 1: Fluorinated Chemicals Production Sector – Reporting Schedule by Subpart**

| Subpart | Source Category | Applicability | First Reporting Year |
|---|---|---|---|
| L | Fluorinated Gas Production | Facilities that would emit ≥ 25,000 metric tons $CO_2e$/year in the absence of emission controls. | 2011 |
| O | HCFC-22 Production, HFC-23 Destruction | All facilities that produce HCFC-22 and facilities not co-located with a HCFC-22 production facility that destroy more than 2.14 metric tons of HFC-23 per year. | 2010 |

**Table 2: Fluorinated Chemicals Production Sector – Number of Reporters (2010–2012)**

| Source Category | Number of Reporters | | |
|---|---|---|---|
| | 2010 | 2011 | 2012 |
| **Total Fluorinated Chemicals Production Sector** | **--[a]** | **16[b]** | **16[b]** |
| Fluorinated Gas Production | --[a] | 16 | 16 |
| HCFC-22 Production, HFC-23 Destruction | 5 | 5 | 5 |

[a] Facilities began reporting emissions under Subpart L in reporting year 2011.

[b] All Subpart O reporters also produce other fluorinated chemicals and, therefore, also report under Subpart L. So there are a total of 16 facilities reporting in 2011 and 2012.

**Table 3: Fluorinated Chemicals Production Sector – GHGRP Coverage**

| Source Category | GHGRP Coverage of Industry | Estimated Percent of Industry Facilities Covered by GHGRP | Estimated Percent of Industry Emissions Covered by GHGRP |
|---|---|---|---|
| Fluorinated Gas Production | Facilities that would emit ≥ 25,000 metric tons $CO_2e$/year in the absence of emission controls. | 89%[a] | >95%[b] |

[1] Sixth Climate Action Report (draft), available at: http://www.state.gov/e/oes/climate/ccreport2014/index.htm.

[2] The total U.S. GHG emissions are 6,525.6 MMT $CO_2e$ as reported in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. U.S. Environmental Protection Agency. April 15, 2014. EPA 430-R-14-003. Available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2012.

| | | | |
|---|---|---|---|
| HCFC-22 Production, HFC-23 Destruction | All facilities that produce HCFC-22, and facilities not co-located with a HCFC-22 production facility that destroy more than 2.14 metric tons of HFC-23 per year. | 100% | 100% |

[a] Estimate of size of industry was based on data reported by suppliers of fluorinated gases (GHGRP Subpart OO). Two fluorinated gas production facilities are estimated to fall below the Subpart L reporting threshold.

[b] Assuming that emissions from the two non-reporting facilities are equal to 1.5 percent of their $CO_2e$ production, the midpoint of the range of estimated emission rates for this sector[3], emissions from these facilities account for less than 5 percent of total emissions from fluorinated gas production.

## Reported Emissions

HCFC-22 producers and HFC-23 destruction facilities reported their emissions to the GHGRP for reporting years 2010, 2011, and 2012. Producers of other fluorinated gases reported their emissions in reporting years 2011 and 2012. For these reporting years, producers of other fluorinated gases reported their total facility emissions only in $CO_2e$. However, by March 31, 2015, facilities will provide more detailed reports for reporting years 2011 through 2014, including chemical-specific reports of most of their emissions.

**Table 4: Fluorinated Chemicals Production Sector – Emissions by Subsector (2010–2012)**

| Fluorinated Chemicals Production Sector | Emissions (MMT $CO_2e$)[a] | | |
|---|---|---|---|
| | 2010 | 2011 | 2012 |
| **Total Fluorinated Chemicals Production Sector[b]** | **N/A** | **13.9** | **11.7** |
| Fluorinated Gas Production | N/A[b] | 6.1 | 6.6 |
| Stationary Fuel Combustion[c] | N/A[b] | 0.9 | 0.7 |
| HCFC-22 Production, HFC-23 Destruction | 7.0 | 6.9 | 4.3 |

[a] Represents total emissions reported to the GHGRP from this industry. Additional emissions may occur at facilities that have not reported; for example, those below the reporting threshold.

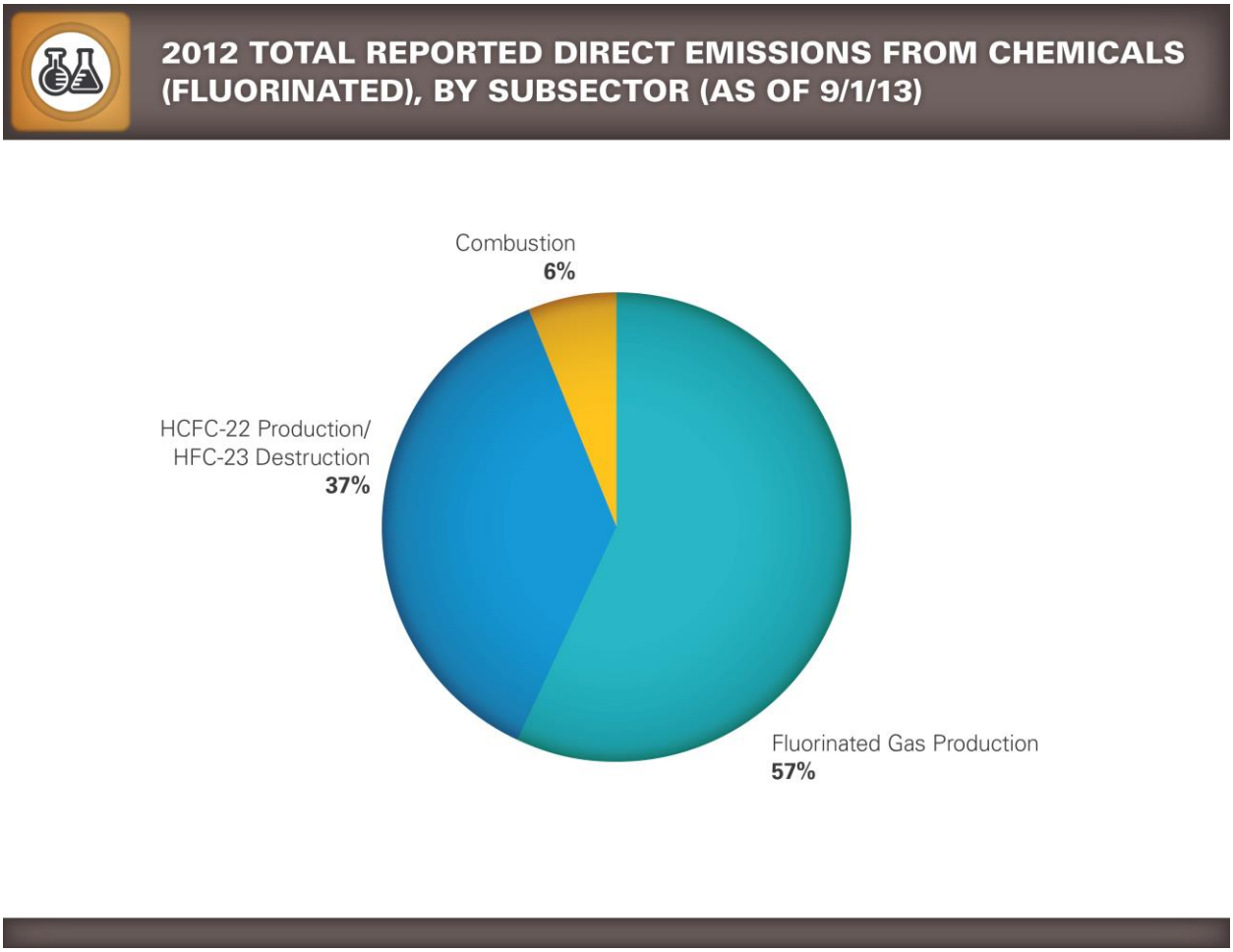
[b] Facilities began reporting emissions under Subpart L in reporting year 2011.

[c] Emissions from fuel combustion are provided here for informational purposes. Generally throughout this document, these emissions are included in the total presented for Fluorinated Gas Production.

Note: Totals may not sum due to independent rounding

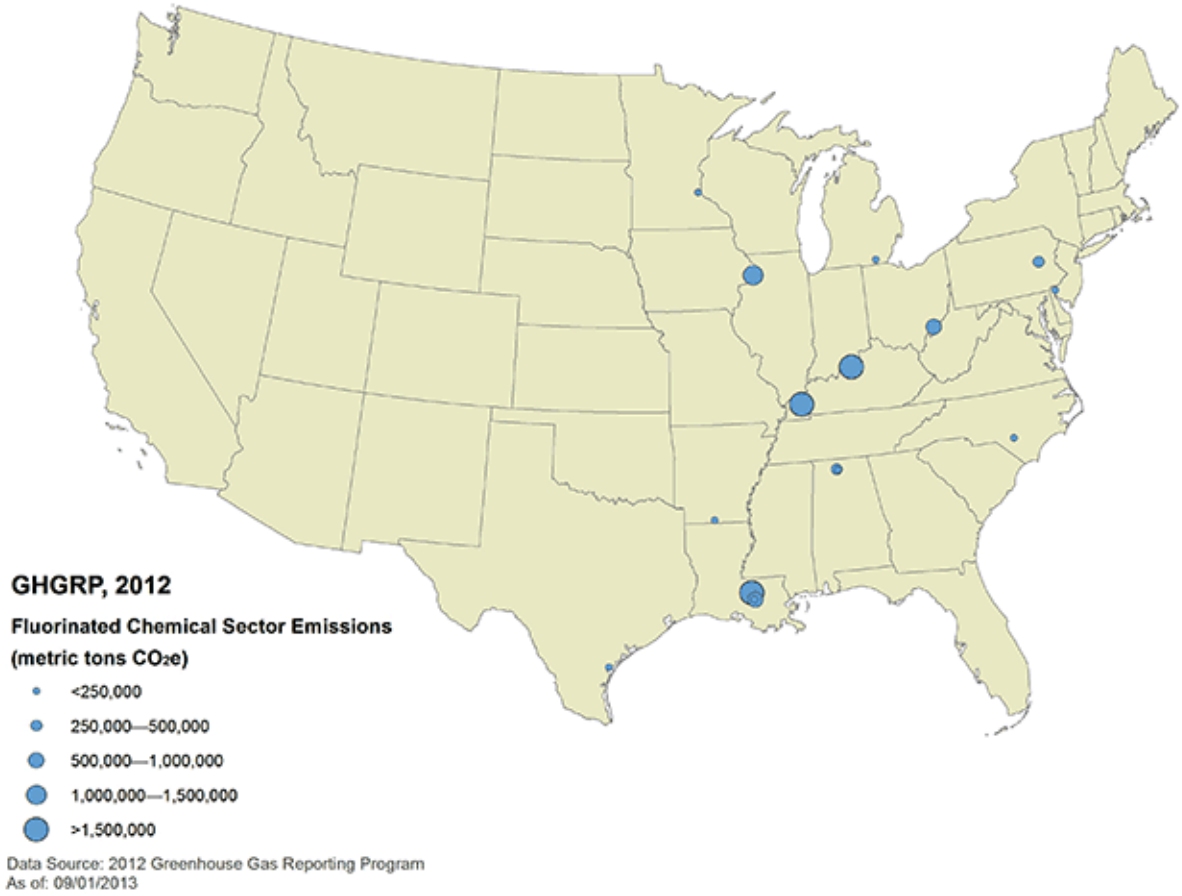
[3] Based on the emissions rate for HCFC-22(2006 IPCC Guidelines, Volume 3, section 3.10.2.1), which is expected to be similar to other fluorinated GHG production processes.

**Figure 1: Fluorinated Chemicals Production Sector – Emissions by Subsector (2012)**




Click here to view the most current information for 2012 using FLIGHT.

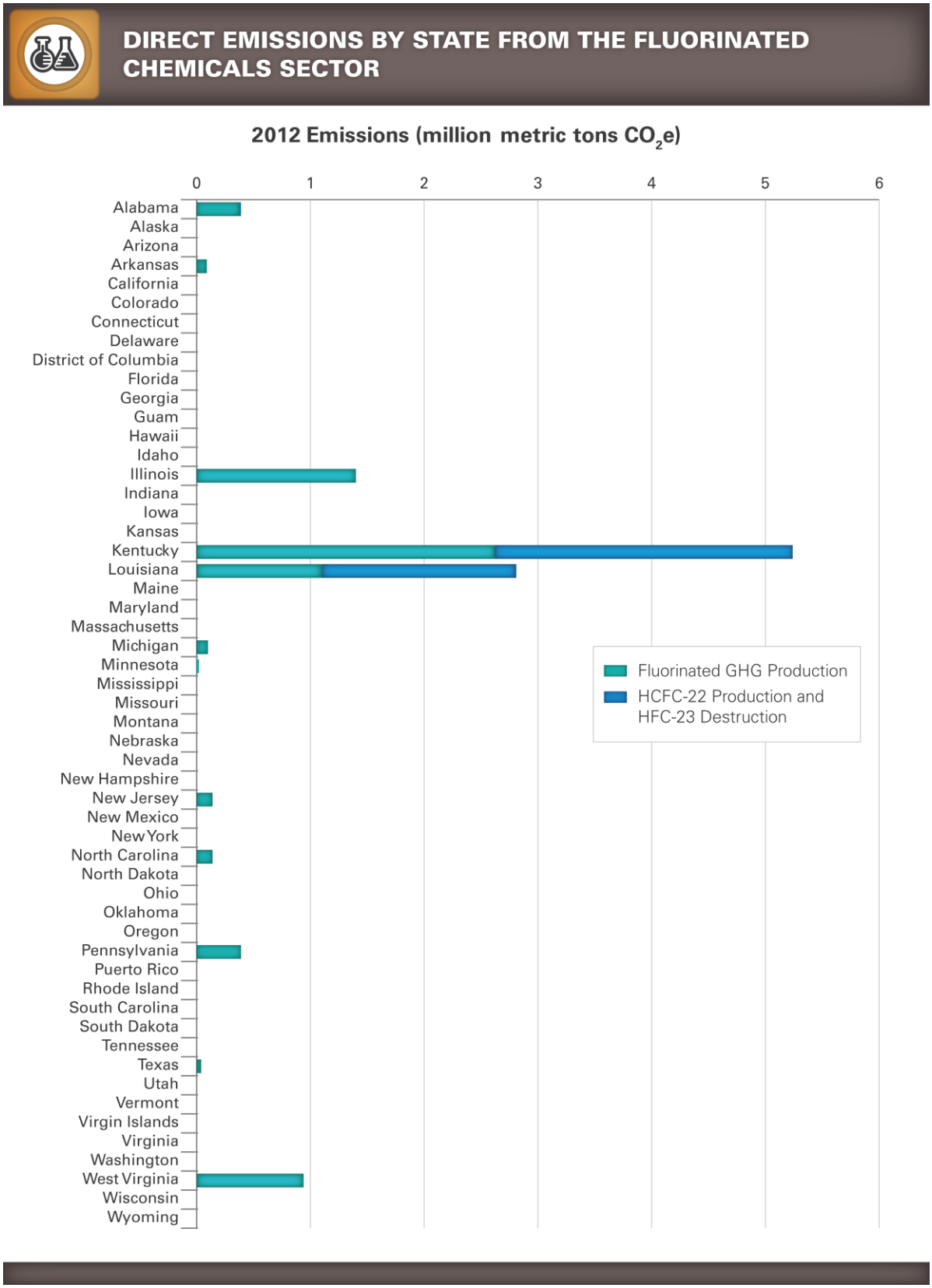
**Figure 2: Location and Emissions Range for Each Reporting Facility in the Fluorinated Chemicals Production Sector (as of 9/1/13)**




This map shows the locations of direct-emitting facilities. The size of a circle corresponds to the quantity of emissions reported by that facility. Fluorinated chemical producers are concentrated along the Mississippi River and its tributaries.

Readers can identify the largest emitting facilities by visiting the Facility Level Information on Greenhouse Gases (FLIGHT) website (http://ghgdata.epa.gov).

**Figure 3: Fluorinated Chemicals Production Sector – Emissions by State (2012)[a]**




[a] Represents total emissions reported to the GHGRP from this industry. Additional emissions may occur at facilities that have not reported, such as those below the reporting threshold.

Click here to view the most current information for 2012 using FLIGHT.

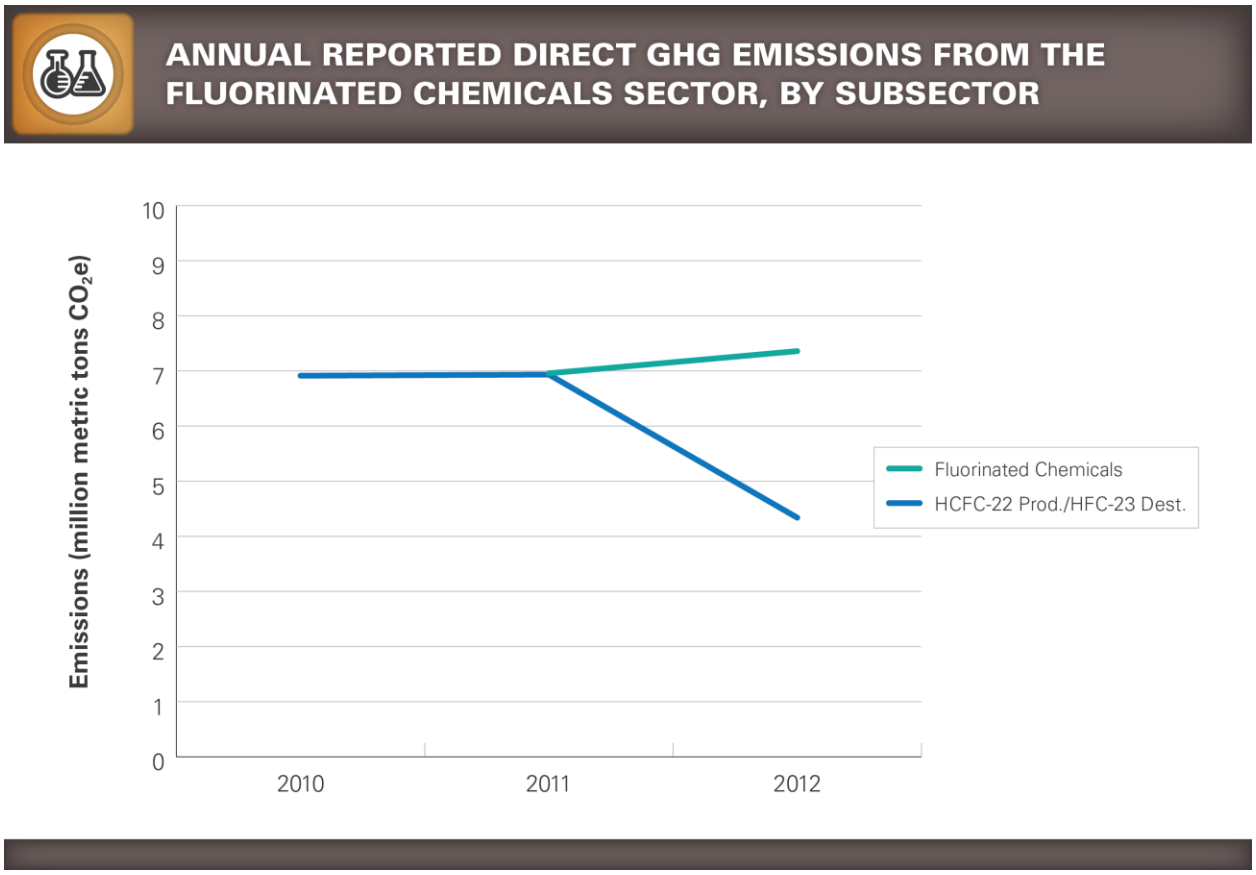
## Fluorinated Chemicals Production Sector Emissions Trends 2010 to 2011

Emissions from HCFC-22 Production and HFC-23 Destruction were steady between 2010 and 2011. (Fluorinated gas producers reported for the first time in 2011 and are therefore not included in this trend).

## Fluorinated Chemicals Production Sector Emissions Trends 2011 to 2012

Fluorinated Chemicals Production Sector emissions were approximately 2.2 MMT $CO_2e$ lower in 2012 than in 2011 (a 16% decrease). Although emissions for Fluorinated Gas Production increased by 0.4 MMT $CO_2e$, overall emissions decreased due to a reduction of 2.6 MMT $CO_2e$ in the HCFC–22 Production, HFC–23 Destruction industry. This reduction was driven both by decreased emissions per unit production and by decreased HCFC-22 production in RY 2012.

**Figure 4: Fluorinated Chemicals Production Sector – Emissions Trend (2010–2012)**




Click here to view the most current information using FLIGHT.

**Table 5: Fluorinated Chemicals Production Sector – Emissions by GHG (MMT $CO_2e$)[a]**

| Fluorinated Chemicals Production Sector | Reporting Year | | |
|---|---|---|---|
| | 2010 | 2011 | 2012 |
| **Number of facilities** | N/A | 16 | 16 |
| **Total emissions (MMT $CO_2e$)** | N/A | 13.9 | 11.7 |
| **Emissions by GHG** | | | |
| **Carbon dioxide ($CO_2$)** | | | |
| • Fluorinated Gas Production | N/A | 0.9 | 0.7 |
| • HCFC-22 Production / HFC-23 Destruction | 0.6 | 0.0[a] | 0.0[a] |
| **Methane ($CH_4$)** | | | |
| • Fluorinated Gas Production | N/A | **[b] | **[b] |
| • HCFC-22 Production / HFC-23 Destruction | **[b] | 0.0[a] | 0.0[a] |
| **Nitrous oxide ($N_2O$)** | | | |
| • Fluorinated Gas Production | N/A | **[b] | **[b] |
| • HCFC-22 Production / HFC-23 Destruction | **[b] | 0.0[a] | 0.0[a] |
| **Total fluorinated GHGs** | | | |
| • Fluorinated Gas Production (emissions are HFCs, PFCs, $SF_6$, $NF_3$, and others) | N/A | 6.1[c] | 6.6[c] |
| • HCFC-22 Production / HFC-23 Destruction (emissions are HFC-23) | 6.4 | 6.9 | 4.3 |

[a] Subpart L facilities were required to begin reporting in reporting year 2011.

[b] Subpart O facilities are all co-located with Subpart L facilities. Combustion emissions were assigned to Subpart O in 2010 and to Subpart L in 2011 and 2012.

[c] For reporting years 2011 and 2012, Subpart L facilities were not required to report emissions of individual fluorinated gases, but report the total $CO_2e$ for the facility.

** Total reported emissions are less than 0.05 MMT $CO_2e$.

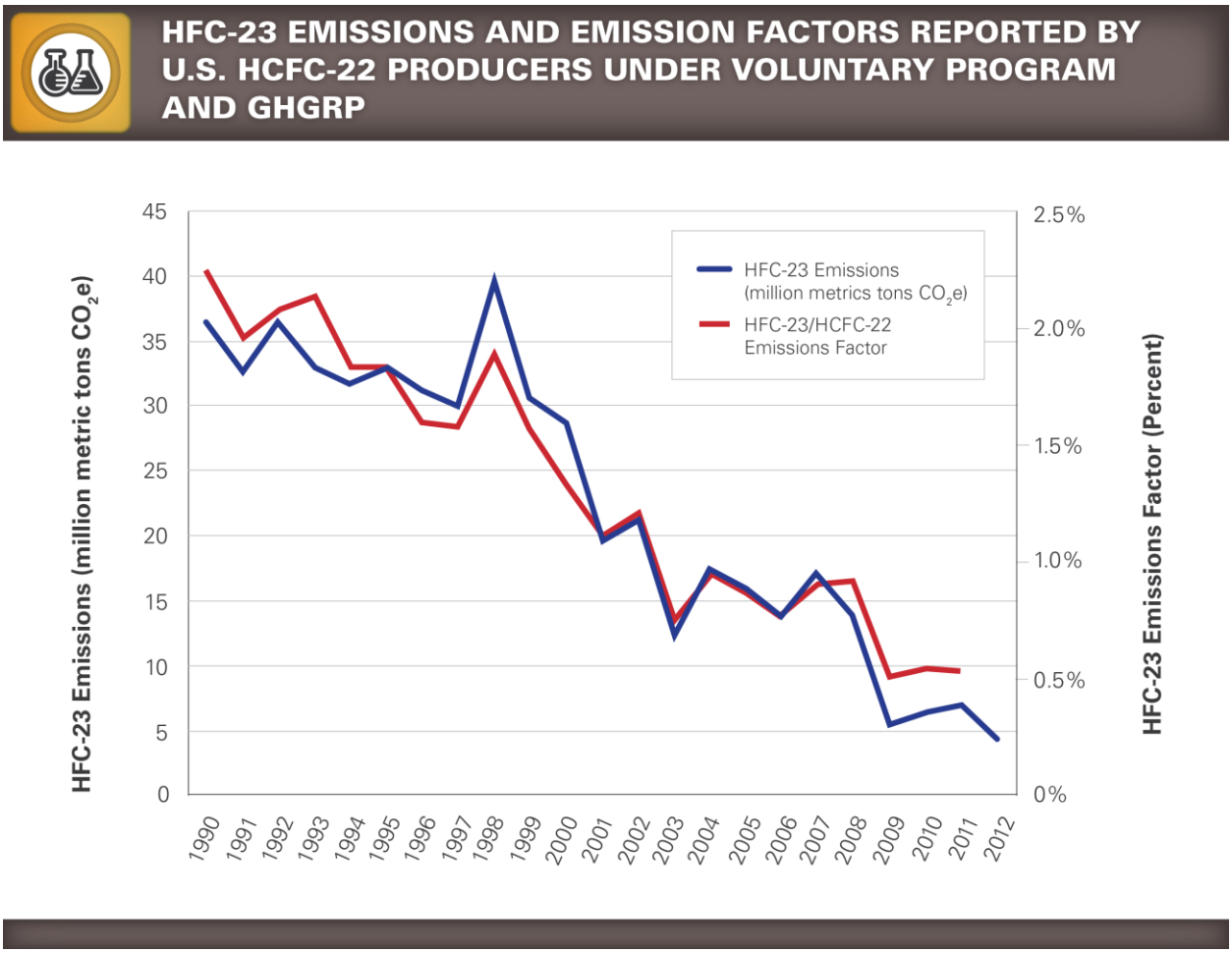
Note: Totals may not sum due to independent rounding.

## Emissions from HCFC-22 Production Before 2010

From 1995 through 2010, U.S. HCFC-22 producers reported their combined HFC-23 emissions and combined HCFC-22 production to EPA under a voluntary program. The emissions reported under the voluntary program are comparable to those reported under the GHGRP, covering essentially the same set of facilities (with the exception of one low-emitting HFC-23 destruction facility) and being based on the same emission estimation methods. The HFC-23 emissions and emission rate (tons HFC-23/ton HCFC-22) reported under the program and under the GHGRP are shown in Figure 5, below.

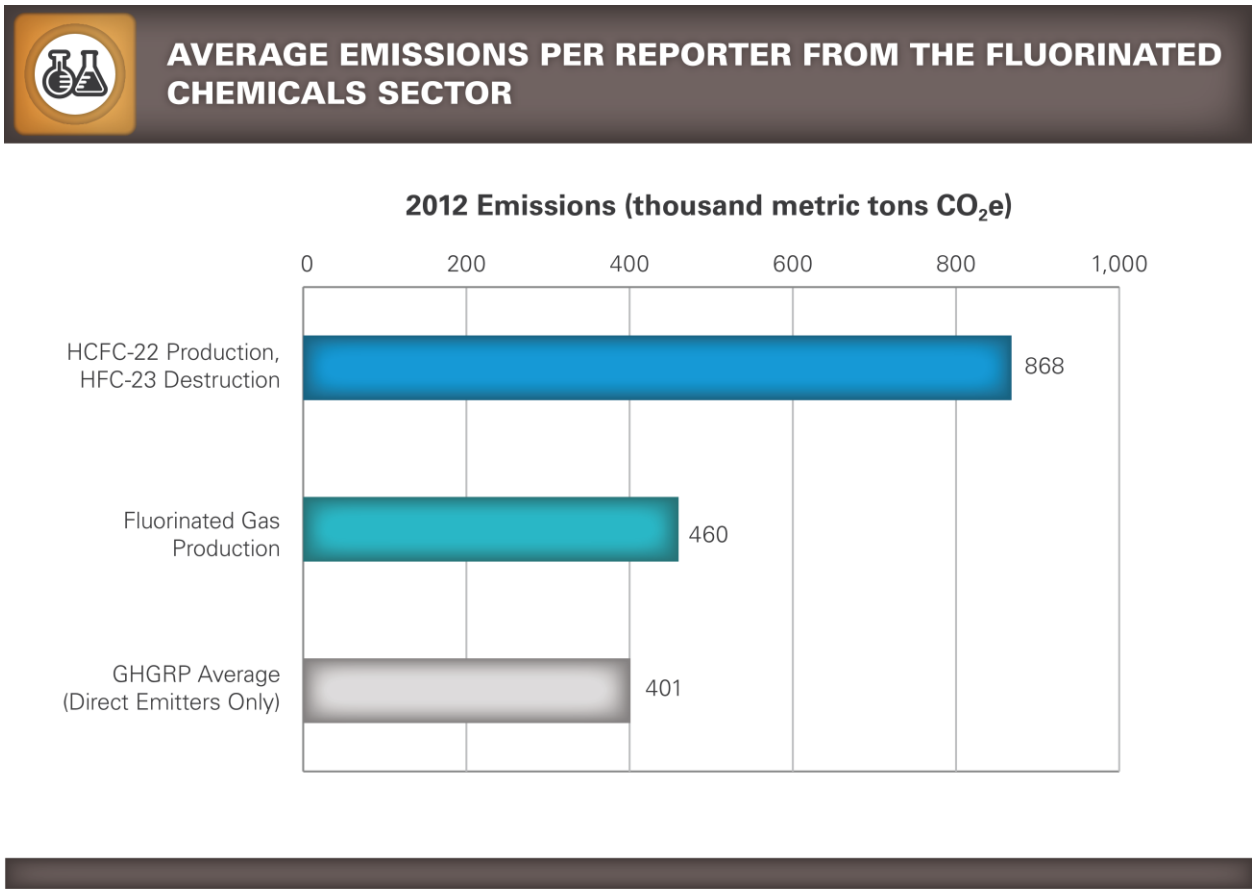
The 81% decline between 1990 emissions and 2011 emissions was due to a 21% decrease in HCFC-22 production and a 76% decrease in the HFC-23 emission rate after 1990. The decrease in the emission rate was primarily attributable to five factors: (a) five plants that did not capture and destroy the HFC-23 generated ceased production of HCFC-22 after 1990, (b) one plant that captures and destroys the HFC-23 generated began to produce HCFC-22, (c) one plant implemented and documented a process change that reduced the amount of HFC-23 generated, (d) the same plant began recovering HFC-23, primarily for destruction and secondarily for sale, and (e) another plant began destroying HFC-23.

**Figure 5: HFC-23 Emissions and Emission Rates per unit Production Reported by U.S. HCFC-22 Producers under Voluntary Program and GHGRP**




Due to the high global warming potentials of many fluorinated GHGs, including HFC-23, the per-facility emissions from fluorinated gas production are relatively high, with 11 out of 16 facilities emitting more than 100,000 MT $CO_2e$ and 4 out of 16 facilities emitting more than 1,000,000 MT $CO_2e$. HCFC-22 Production/HFC-23 Destruction facilities reported average emissions of roughly 868,000 MT $CO_2e$ from those activities, while producers of other fluorinated gases reported average emissions of roughly 460,000 MT $CO_2e$. However, all HCFC-22 producers also produce other fluorinated gases, leading to average facility emissions of roughly 730,000 MT $CO_2e$. These figures compare to average per-facility emissions of 401,000 metric tons $CO_2e$ for all GHGRP facilities and 168,000 metric tons $CO_2e$ for GHGRP facilities other than electricity generators (Figure 6).

**Figure 6: Fluorinated Chemicals Production Sector – Average Emissions per Reporter (2012)[a]**




[a] All HCFC-22 Production/HFC-23 Destruction facilities also produce other fluorinated gases. Emissions from fuel combustion from each facility are assigned to fluorinated gas production rather than to HCFC-22 production. Emissions from fuel combustion comprise nine percent of the emissions attributed to fluorinated gas production (see Table 4).

**Figure 7: Number of Reporters by Total Reported Direct Emissions (2012)**
(Includes emissions from both HCFC-22 and Other Fluorinated Gas Production)

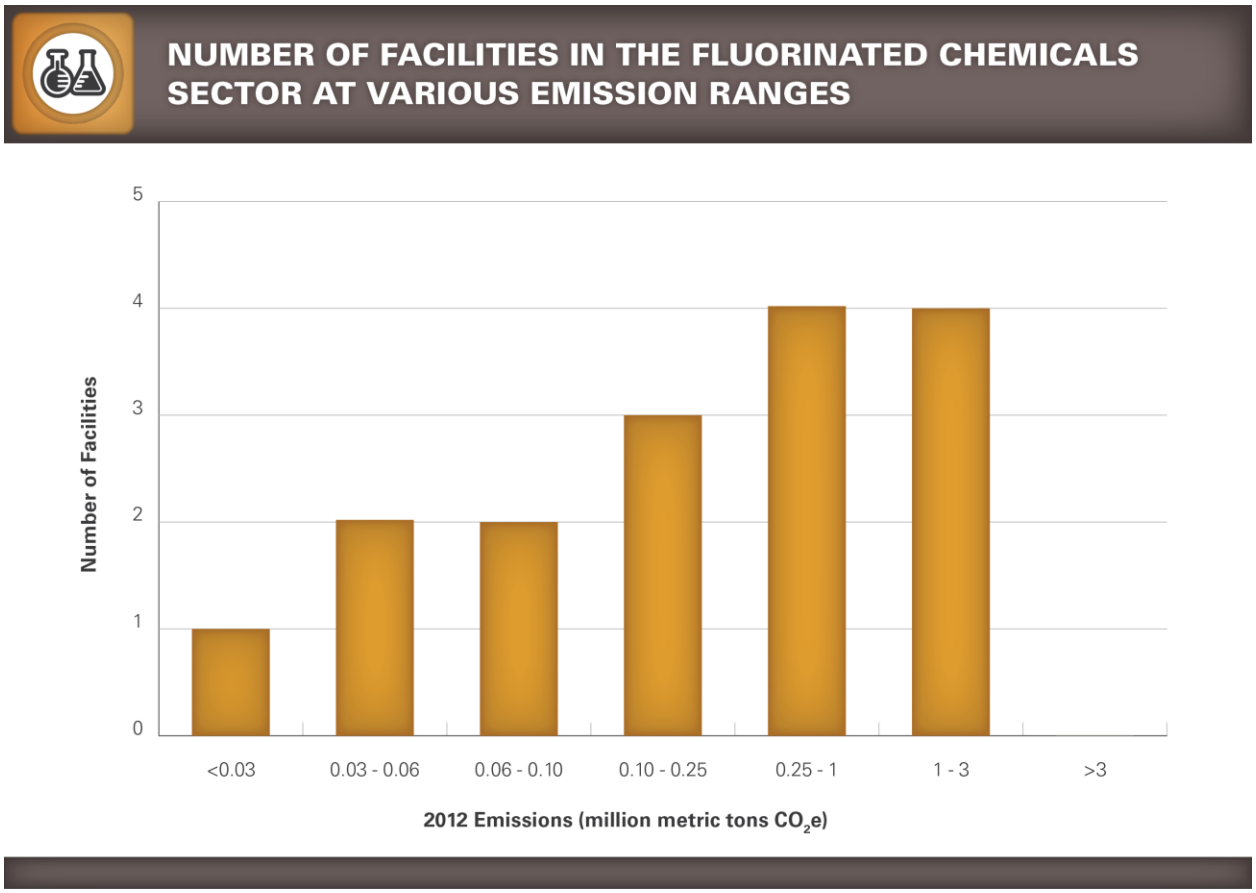


**Figure 8: Percentage of Reporters by Range of Emissions (2012)**

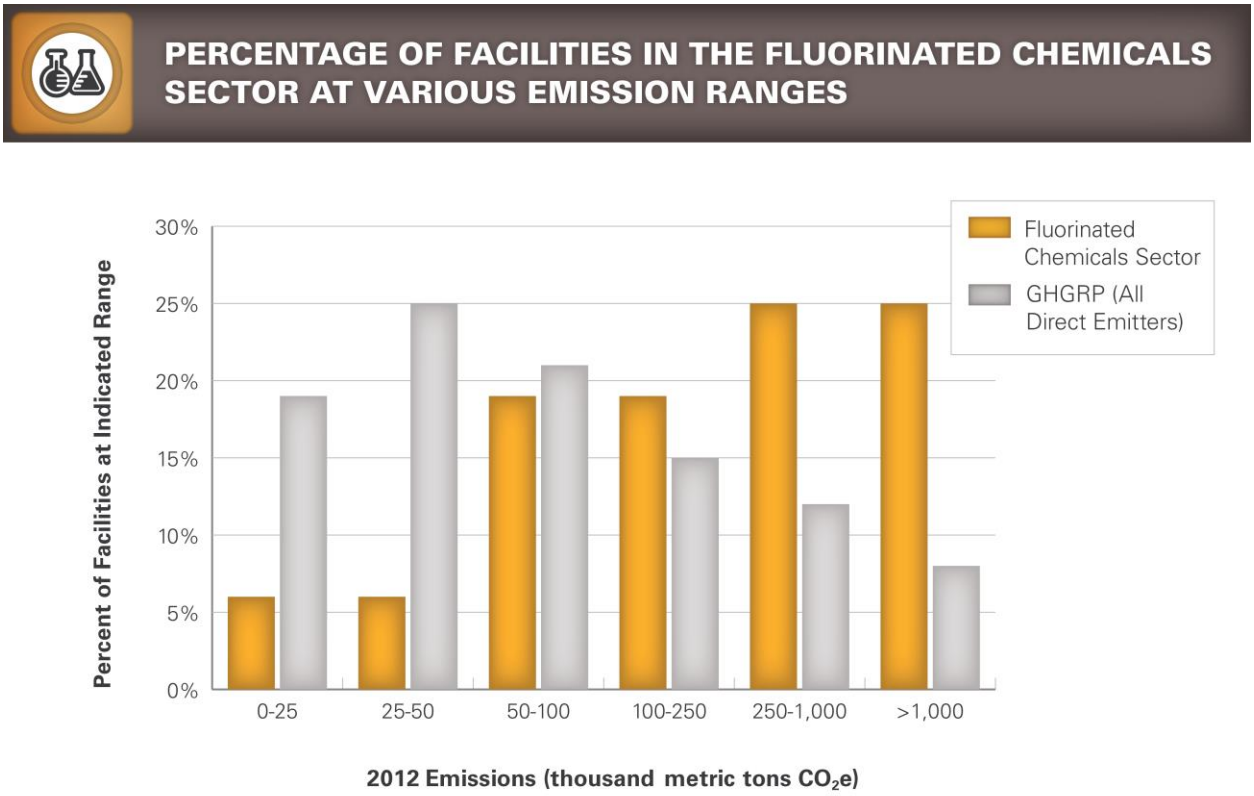


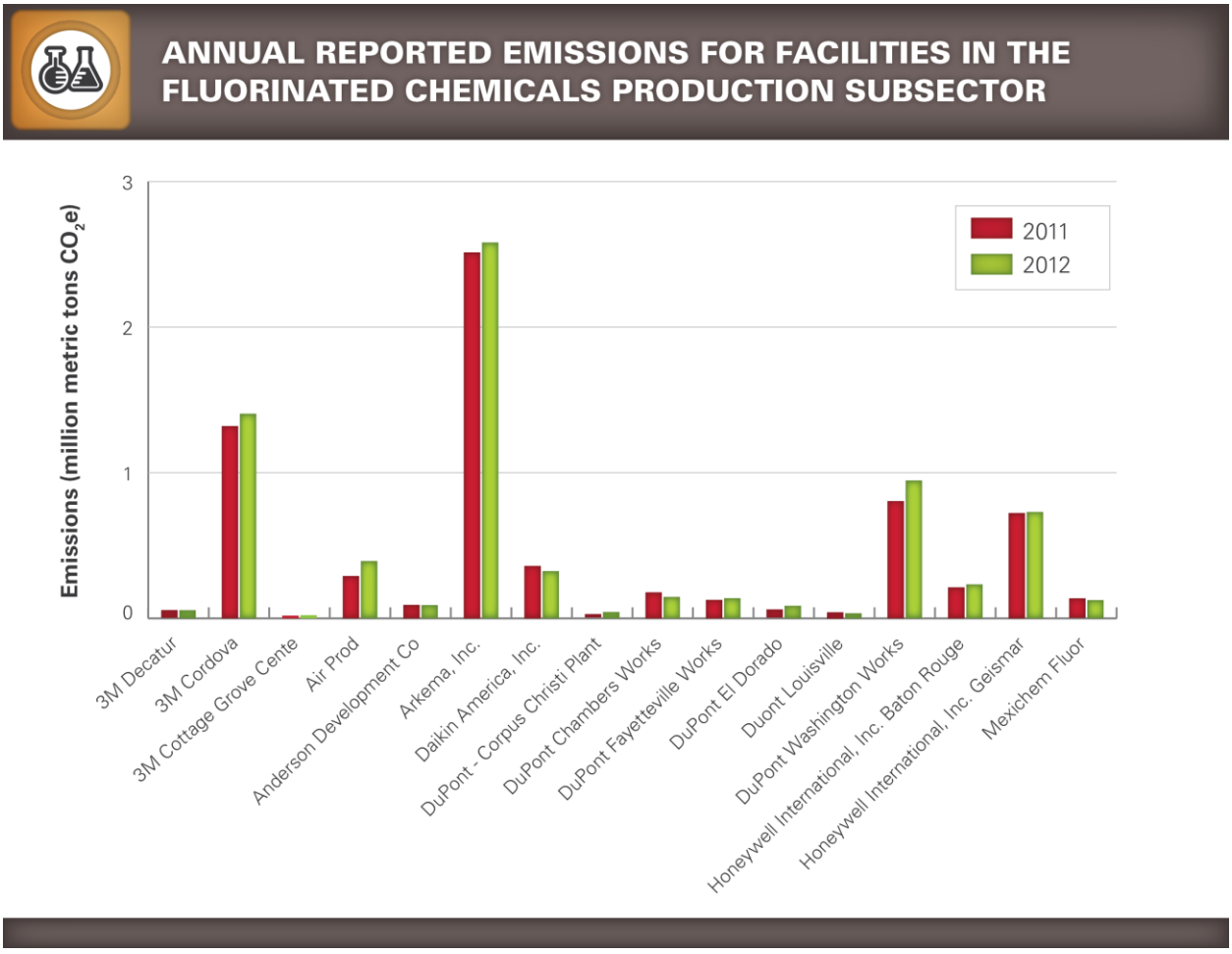

**Table 6: Fluorinated Chemicals Production Sector – Emissions by Facility, by Subsector (2012)** [a]

| Name | Emissions (MMT $CO_2e$) | Location |
|---|---|---|
| **Fluorinated Gas Production** | | |
| Arkema, Inc. | 2.6 | Calvert City, KY |
| 3M Cordova | 1.4 | Cordova, IL |
| DuPont Washington Works | 0.94 | Washington, WV |
| Honeywell International Inc - Geismar Complex | 0.73 | Geismar, LA |
| Air Products | 0.39 | Tamaqua, PA |
| Daikin America, Inc. | 0.32 | Decatur, AL |
| Honeywell International, Inc. Baton Rouge | 0.23 | Baton Rouge, LA |
| DuPont Fayetteville Works | 0.14 | Fayetteville, NC |
| DuPont Chambers Works | 0.14 | Deepwater, NJ |
| Mexichem Fluor | 0.13 | Saint Gabriel, LA |
| Anderson Development Co | 0.097 | Adrian, MI |
| DuPont El Dorado | 0.091 | El Dorado, AR |
| 3M Decatur | 0.055 | Decatur, AL |
| DuPont - Corpus Christi Plant | 0.039 | Gregory, TX |
| DuPont Louisville | 0.032 | Louisville, KY |

| Name | Emissions (MMT $CO_2e$) | Location |
|---|---|---|
| 3M Cottage Grove Center | 0.022 | Cottage Grove, MN |
| **HCFC-22 Production, HFC-23 Destruction** | | |
| DuPont Louisville Works | 2.6 | Louisville, KY |
| Honeywell International Inc - Baton Rouge Plant | 1.7 | Baton Rouge, LA |
| Honeywell International Inc - Geismar Complex | <0.01 | Geismar, LA |
| Daikin America, Inc. | <0.01 | Decatur, AL |
| DuPont Washington Works | <0.01 | Washington, WV |

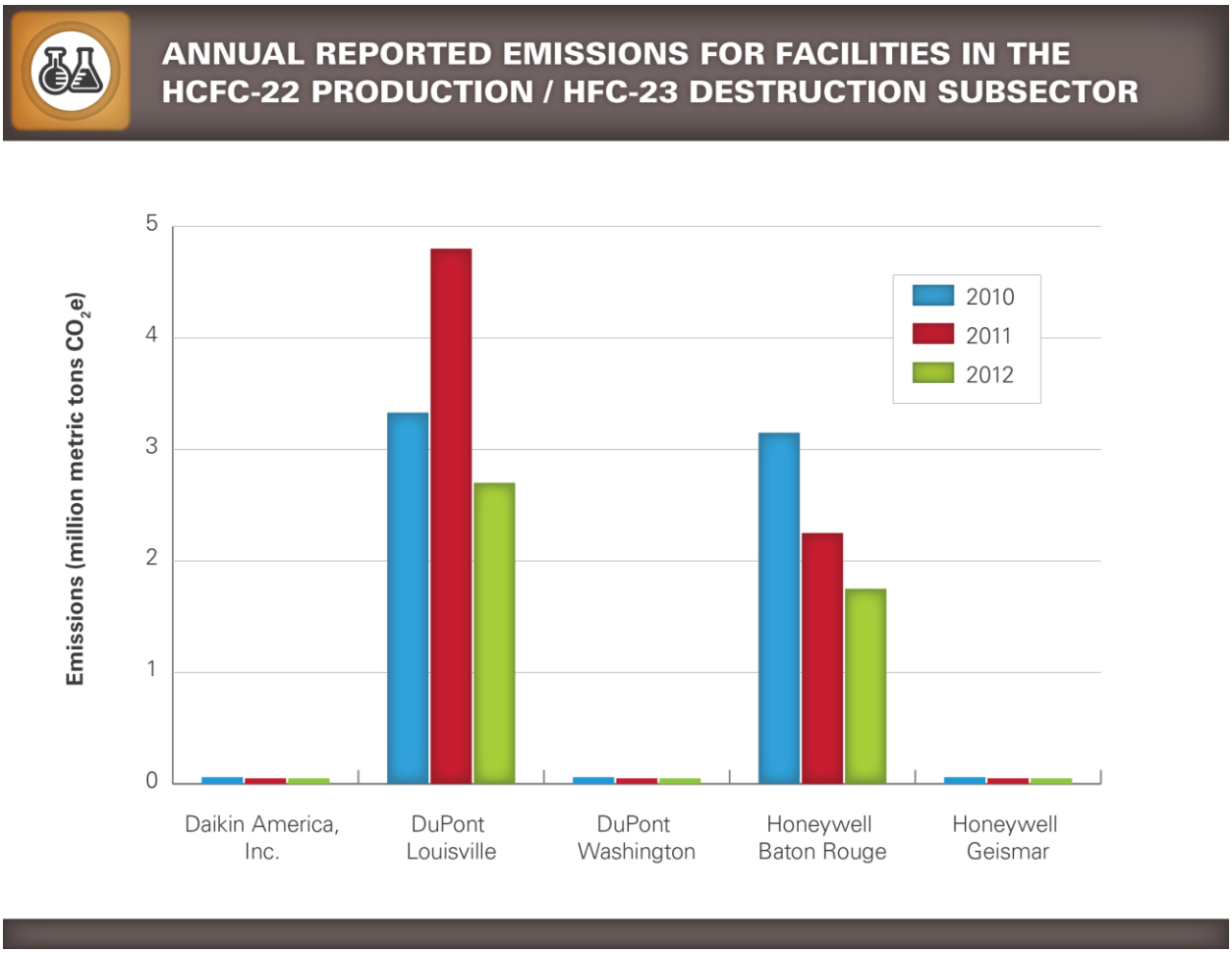
[a] This table lists all facilities that submitted reports for reporting year 2012.

**Figure 9: Fluorinated Chemicals Production Sector Total Facility Emissions (MMT $CO_2e$) by Year[a]**




[a] Includes combustion emissions.

**Figure 10: HCFC-22 Production / HFC-23 Destruction Total Facility Emissions (MMT $CO_2e$) by Year**




## Calculation Methods Used

The production of fluorinated chemicals results in both process-related emissions (fluorinated greenhouse gas emissions from manufacturing and gas destruction processes) and fuel combustion emissions ($CO_2$, $CH_4$, and $N_2O$ from the burning of fuel for energy).

### Stationary Fuel Combustion Emissions

Facilities must report any emissions from stationaly fuel combustion sources by following the calculation methods of 40 CFR part 98, Subpart C (General Stationary Combustion Sources). The calculation methodologies for Subpart C are explained here.

### Process Emissions

Facilities in the Fluorinated Chemicals Production Sector can use one of several different methodologies to report their process emissions, depending on the subsector.

For HCFC-22 Production and HFC-23 destruction (Subpart O), facilities use different calculations to estimate HFC-23 emissions depending upon whether or not the facility has an HCFC-22 production process that is directly connected to a destruction device.

- **Process Measurements** – This method is used by facilities whose HCFC-22 production processes are not directly connected to a destruction device. The generation of HFC-23 is measured in the process, and a mass balance is performed to determine the amount emitted after accounting for any HFC-23 destroyed on site, sent offsite for destruction or for sale, or added to an on-site inventory.
- **Emissions Measurements** – This method is used by facilities whose HCFC-22 production processes are directly connected to a destruction device. An emissions test is required for the process vents every five years, and the results of the emissions test are used to estimate process vent emissions. These process vent emissions are added to estimates of emissions from equipment leaks and from destruction processes.
- **Emissions from Destruction Devices** – This method is used by facilities that destroy HFC-23 but do not contain an HCFC-22 production process. The destruction efficiency (DE) of the destruction device is multiplied by the amount of HFC-23 fed into the device to calculate the amount destroyed and the emissions from the device. The results are used to estimate emissions under the "Emissions Measurements" method, under the "Process Measurements" method (if applicable), or from destruction devices that are not co-located with HCFC-22 production processes. The DE must be equated to the DE determined during a new or previous performance test of the destruction device. The DE of the destruction device must be confirmed annually, and if necessary, revised.

**Table 7: HCFC-22 Production, HFC-23 Destruction – Methodologies**

| Type of Emissions | Methodology | Percentage of Emissions Monitored by Method (by Type) | | |
|---|---|---|---|---|
| | | 2010 | 2011 | 2012 |
| Process Emissions | Process measurements | 51.4% | 67.9% | 60.3% |
| | Emissions measurements | 48.6% | 32.0% | 39.2% |
| | Destruction processes that are not co-located with HCFC-22 production processes | <0.1% | 0.1% | 0.5% |
| Combustion Emissions | Measured high heating values (HHVs) and default emission factors (Tier 2) | 82.5% | N/A[a] | N/A[a] |
| | Default HHVs and emission factors (Tier 1) | 17.5% | N/A[a] | N/A[a] |

[a] N/A indicates not applicable, as each of the facilities that reported under Subpart O in RY 2010 subsequently reported under Subpart L in RY 2011 and RY 2012, and the combustion emissions reported under Subpart C for these facilities in RY 2011 and RY 2012 are attributed to Subpart L, Fluorinated GHG Production.

For fluorinated gas production (Subpart L), facilities may estimate fluorinated GHG emissions using a mass-balance approach, an emission factor approach, or an emission calculation factor approach. Emissions must also be calculated for destruction processes and for venting of residual gas from containers. Emissions for the year 2011 and 2012 were reported in $CO_2e$ only. For fluorinated GHGs that do not have a global warming potential listed in Table A-1, facilities are required to use either a default GWP or their best estimate of the GWP.

- **Mass-balance** – The mass balance approach may be used if the facility meets the error criteria specified in the rule for measuring each of the process inputs and outputs.
- **Process-vent-specific emission factors** – For vents from continuous processes with annual controlled emissions greater than 10,000 MT $CO_2e$, emissions testing is required to establish an emission factor. Equipment leak estimates must also be made.

- **Process-vent-specific emission calculation factors** – For vents from batch processes and vents from continuous processes with annual controlled emissions of less than 10,000 MT $CO_2e$, engineering calculations or assessments may be used to establish a vent-specific emission factor. Equipment leak estimates must also be made.

**Table 8: Fluorinated Gas Production – Methodologies**

| Type of Emissions | Methodology | Percentage of Emissions Monitored by Method (by Type) | | |
|---|---|---|---|---|
| | | 2010[a] | 2011 | 2012 |
| Process Vent[b] | Emission factors (vent test) | -- | 4.2% | 3.7% |
| | Emission calculation factors | -- | 16% | 13% |
| Process – Equipment Leak Estimation[c] | Average emission factor approach | -- | 51% | 15% |
| | Screening ranges approach with Method 21 | -- | 0.62% | 0.05% |
| | EPA correlation approach with Method 21 | -- | 3.2% | 1.9% |
| | Screening range approach[d] | -- | >0% | >0% |
| | EPA correlation approach in conjunction with site-specific leak monitoring method[d] | -- | >0% | >0% |
| | Unit specific correlation approach in conjunction with site specific leak monitoring method[d] | -- | >0% | >0% |
| | Other site specific leak monitoring methods | -- | 17% | 17% |
| Fuel Combustion | Measured high heating values (HHVs) and default emissions factors (Tier 2) | -- | 65.0% | 68.8% |
| | Default HHVs and emission factors (Tier 1) | -- | 35.0% | 31.2% |

[a] The initial reporting year for Subpart L facilities was RY 2011.

[b] For RY2011, this table covers approximately 20% of the process emissions. The balance of emissions in the Subpart L source category occur at facilities that use more than one mass emission method, i.e. both process vent emission factors and process vent emission calculation factors; these facilities using more than one method account for approximately 80% of emissions for RY2011.

[c] For RY2011, the table covers approximately 72% of the equipment leak emissions, and the balance of emissions from EL in the Subpart L source category occur at facilities that use more than one EL method to estimate these emissions. These facilities using more than one method account for 28% of EL emissions in RY2011.

[d] All facilities that used each of these methodologies also used additional equipment leak methods; while we can confirm that some emissions could be apportioned for these methods, we are not able to determine the percentage of emissions calculated for these methodologies.

### Best Available Monitoring Methods (BAMM)

During the first year that the GHGRP applied, facilities were allowed to optionally use a best available monitoring method (BAMM) to determine emission inputs for specific emissions sources for a limited amount of time. The use of BAMM was allowed because it was not always feasible for a newly subjected facility to acquire, install, and operate all of the required monitoring equipment by the date required by the GHGRP. EPA's BAMM provision provided time for these facilities to replace their equipment in a way that could minimize impacts to normal business operations. Subpart O facilities were allowed to use BAMM from January1, 2010 to March 31, 2010. Subpart L facilities were allowed to use BAMM from January 1, 2011 to June 30, 2011 and under limited circumstances thereafter. Learn more about BAMM.

**Table 16: BAMM Use as Percent of Facilities**

| BAMM Use | 2010 | 2011 | 2012 |
|---|---|---|---|
| Fluorinated Gas Production | N/A | 19% | 12% |
| HCFC-22 Production, HFC-23 Destruction | 20% | Not allowed | Not allowed |

## Data Verification and Analysis

As a part of the reporting and verification process, EPA evaluates annual GHG reports with electronic verification checks. EPA contacts facilities regarding potential reporting issues. Statistics related to EPA's verification of reports from this sector are provided below. Additional information on EPA's verification process is available here.

## Potential for Emission Reductions

### HCFC-22 Production and HFC-23 Destruction

Options for reducing emissions of fluorinated GHGs from fluorinated chemical production include process optimization (e.g. to decrease generation of by-products), destruction (e.g., thermal oxidation and plasma arc), capture (which only delays emissions unless the captured gas is later transformed, used to displace other fluorinated GHG products, or destroyed), recovery rather than venting of residual fluorinated GHG products in returned containers, and leak detection and repair (for emissions from equipment leaks).

As discussed above, HCFC-22 producers have greatly reduced both their HFC-23 emissions and their HFC-23 emissions rate per unit production (tons HFC-23/ton HCFC-22) since 1990. To reduce the emission rate one producer has optimized the HCFC-22 production process to reduce the generation of the HFC-23 by-product, and all producers have implemented HFC-23 destruction programs, to varying extents. As a result of these efforts, 2012 HFC-23 emissions were approximately one fifth as large as they would be if facilities had continued to emit at the 1990 rate. Nevertheless, opportunities for significant additional reductions remain. According to the report, *Global Mitigation of Non-$CO_2$ Gases*, consistent use of HFC-23 destruction devices can reduce uncontrolled emissions by 95%.[4] This implies that the current U.S. emission factor could be reduced by an additional 75%, resulting in reductions of approximately 3 MMT $CO_2$e. According to *Global Mitigation of Non-$CO_2$ Gases*, the cost of HFC-23 destruction is between $0 and $1 per ton of $CO_2$e reduced.

Less is known regarding the potential for reducing emissions from production of fluorinated gases other than HCFC-22. Production processes for different fluorinated gases are believed to have significantly varying by-product generation rates and emission rates, and relatively little information is available on these rates and the extent to which they have already been decreased. At least some facilities are known to employ destruction devices to decrease emission rates. However, as is true for HCFC-22 production, opportunities for significant additional reductions (i.e. several MMT $CO_2$e) are likely to exist.

[4] Global Mitigation of Non-$CO_2$ Greenhouse Gases: 2010-2030. EPA Publication No. EPA-430-R-13-011. September 2013.

## GLOSSARY

**CFCs** mean chlorofluorocarbons. CFCs are gases covered under the 1987 Montreal Protocol and used for refrigeration, air conditioning, packaging, insulation, solvents, or aerosol propellants. Since they are not destroyed in the lower atmosphere, CFCs drift into the upper atmosphere where, given suitable conditions, they break down ozone.

**BAMM** means Best Available Monitoring Methods. Facilities approved for BAMM may use best available monitoring methods for any parameter (e.g., fuel use, feedstock rates) that cannot reasonably be measured according to the monitoring and QA/QC requirements of a relevant subpart.

**FLIGHT** refers to EPA's GHG data publication tool, named Facility Level Information on Greenhouse Gases Tool (http://ghgdata.epa.gov).

**Fluorinated greenhouse gas** means sulfur hexafluoride ($SF_6$), nitrogen trifluoride ($NF_3$), and any fluorocarbon except for controlled substances as defined at 40 CFR part 82, Subpart A and substances with vapor pressures of less than 1 mm of Hg absolute at 25 degrees C. With these exceptions, "fluorinated GHG" includes but is not limited to any hydrofluorocarbon, any perfluorocarbon, any fully fluorinated linear, branched or cyclic alkane, ether, tertiary amine or aminoether, any perfluoropolyether, and any hydrofluoropolyether.

**Fluorocarbons:** Carbon-fluorine compounds that often contain other elements such as hydrogen, chlorine, or bromine. Common fluorocarbons include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

**Fluorinated gas** means any fluorinated GHG, CFC, or HCFC.

**GHGRP** means EPA's Greenhouse Gas Reporting Program (40 CFR part 98).

**GHGRP vs. GHG Inventory:** EPA's Greenhouse Gas Reporting Program (GHGRP) collects and disseminates annual greenhouse gas data from individual facilities and suppliers across the U.S. economy. EPA also develops the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks (GHG Inventory) to track total national emissions of greenhouse gases to meet U.S. government commitments to the United Nations Framework Convention on Climate Change. The GHGRP and Inventory datasets are complementary and may inform each other over time. However, there are also important differences in the data and approach. For more information, please see https://www.epa.gov/ghgreporting/greenhouse-gas-reporting-program-and-us-inventory-greenhouse-gas-emissions-and-sinks.

**HFC** means hydrofluorocarbon, which refers to compounds containing only hydrogen, fluorine, and carbon atoms. HFCs are primarily used as alternatives to ozone depleting substances, e.g., as refrigerants and foam blowing agents. In addition, HFCs are emitted as by-products of industrial processes and are also used in magnesium production and processing. They do not significantly deplete the stratospheric ozone layer, but they are powerful greenhouse gases.

**HFE** means hydrofluoether, which is a complex organic solvent that was developed originally as a replacement for CFCs, HFCs, HCFCs, and PFCs.

**Hydrochlorofluorocarbons (HCFCs)** are compounds containing hydrogen, fluorine, chlorine, and carbon atoms. Although ozone depleting substances, they are less potent at destroying stratospheric ozone than chlorofluorocarbons (CFCs). They have been introduced as temporary replacements for CFCs and are also greenhouse gases.

**IPCC AR4** refers to the Fourth Assessment Report by the Intergovernmental Panel on Climate Change. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K. and Reisinger, A. (eds)]. IPCC, Geneva, Switzerland, 2007.* The AR4 values also can be found in the current version of Table A-1 in Subpart A of 40 CFR part 98.

**$NF_3$** means nitrogen trifluoride, a powerful greenhouse gas that is used in electronics manufacturing.

**MMT** means million metric tons.

**PFC** means perfluorocarbon. Perfluorocarbon refers to a group of chemicals composed of carbon and fluorine only. These chemicals (predominantly $CF_4$ and $C_2F_6$) are emitted as by-products of industrial processes and are also used in manufacturing. In addition, PFCs were introduced as alternatives, along with hydrofluorocarbons, to the ozone depleting substances. PFCs do not harm the stratospheric ozone layer, but they are powerful greenhouse gases that remain in the atmosphere for thousands of years.

**$SF_6$** means sulfur hexafluoride. Sulfur hexafluoride is a very powerful greenhouse gas used primarily as an electrical insulator in electrical transmission and distribution systems and as a dielectric in electronics.