PROGRAM FOR ESTIMATING EMISSIONS OF HFCS AND PFCS BY THE FIRE PROTECTION INDUSTRY

Joseph A. Senecal
Combustion Research Center
Kidde-Fenwal, Inc.
90 Brook Street
Holliston, MA 01746 USA
Tel. (508) 429-3190 Fax (508) 429-2990
E-mail joseph.senecal@kidde-fenwal.com

Abstract. On March 25, 2002 the U.S. fire protection industry announced *Voluntary Code of Practice For HFC and PFC Fire Protection Agents.** A central element of the VCOP is the requirement to coordinate the development of a verifiable data tracking system on the emissions of HFCs across the U.S. fire protection industry. This paper describes the development of that data tracking system, the *HFC Emissions Estimating Program*, or HEEP. Additionally, the operation character of the HEEP is given with a goal that it serve as a foundational tutorial to participants in the program.

Introduction. Since 1987, with the promulgation of the Montreal Protocol on Substances that Deplete the Ozone Layer [1], the attention given to the effects of mankind on the quality of the atmosphere by the scientific, industrial and wider world communities has steadily increased. The science of ozone depleting substances (ODSs), especially chlorofluorocarbons (CFCs) and halons, and their socioeconomic management to reverse atmospheric accumulations is well advanced and, by all counts, headed toward achieving goals, even if these are to be reached decades from now. The focus of atmospheric science has now largely shifted from ozone depletion to global warming. Emissions of greenhouse gases (GHGs) , principally carbon dioxide but also methane, nitrous oxide, hydrofluorocarbons (HFCs) , perfluorocarbons (PFCs) and sulfurhexafluoride (SF_6) can lead to retardation of natural radiative cooling of the earth through atmospheric absorption of long wavelength infrared radiation. The consequence is net energy accumulation and temperature rise at the earth's surface. While the earth's energy balance is exceedingly complex, the evidence is clear that human activity is having a small but measurable effect on average global temperature. The Kyoto Protocol [2] has brought world focus to this subject and contains specific goals on GHG emission reductions to be achieved by the signatories. While the U.S. has yet to ratify the Kyoto Protocol the U.S. Environmental Protection Agency has not stood idly by but has continued to promote good environmental practice in general, and policies and practices aimed at containing GHG emissions in particular. The Significant New Alternatives Policy (SNAP) [3] has provided a framework in directing industry and commerce in selecting technologies to fill in the gaps left by the necessary abandonment of the use of CFCs and halons.

Under SNAP a number of chemicals have been identified as suitable alternatives for Halon 1301 for use in the most critical of special hazard fire protection applications, namely, total flood gaseous fire suppression systems. HFCs and PFCs, as well as several inert gas products, are used as extinguishing agents in these systems in applications where the first and foremost concern is personnel safety in normally occupied rooms where the possibility exists that the fire suppression system could discharge without warning when people are present. Additionally, the use of Halon 1211 in portable fire extinguishers has been supplanted in some cases by products containing HFCs and PFCs. Thus, the set of fire protection stakeholders who use chemical agent - from product manufacturers, distributors, installers, service providers, and end users – has a role in the atmospheric environmental subject. The first goal of a

* Public announcement was made at the press briefing of the Earth Technology Forum, Hyatt Regency Capitol Hill, Washington, D.C., March 25, 2002.

fire extinguishing protection system is to provide protection to people and assets. Achieving this goal incurs several types of costs including economic and environmental costs, each of which is to be minimized. The incentives to minimize economic costs relate directly to profitability. The incentives to minimize the environmental impact of a fire extinguishing system strategy employing HFC agents is less obvious but just as important. If industry and commerce are reckless in the use of a public asset, whether it is the atmosphere (stack emissions of acid gases and particulates) or pollution of the ocean (over fishing or flushing oil tanks), the public will demand that its government restrict such behaviors. The prospect of avoiding external regulation can be a strong incentive for an industry to cooperate in establishment of practices favorable to the public interests.

Thus was born the *Voluntary Code of Practice For HFC & PFC Fire Protection Agents* (VCOP), described elsewhere [4]. The essential operative statement within the VCOP is "The U.S. fire protection industry fully supports the goal of eliminating non-fire emissions of fire protection agents, and is committed to continuing to contribute to both ozone layer and climate change protection." The VCOP sets out a number of recommended practices for industry to follow with the goal of reducing the probability of accidental discharge of a fire extinguishing system or other emission of an HFC agent. An important element of the VCOP is the requirement to "Coordinate the development of a verifiable data tracking system on the emissions of HFCs across the U.S. fire protection industry." This follows from the need to quantify emissions over time in order to determine current and future performance and to establish benchmarks and assess changes in emission levels. Development of the HFC Emissions Estimating Program (HEEP) was initiated to serve this goal and is the subject of this paper.

Evolution of the HFC Emissions Estimating Program (HEEP). The Halon Alternatives Research Corporation (HARC), progenitor of the VCOP, at its December 2000 meeting reviewed the comments made by the U.S. Environmental Protection Agency on the then draft version of the VCOP. The inclusion of an emissions estimating element in the VCOP was at the EPA's recommendation. It was agreed that this element would significantly strengthen the VCOP and provide a measurement tool to assess it effectiveness over time. Since the bulk of HFC used in fire extinguishing units are employed in total flood fire extinguishing systems it was clear that the fire suppression systems industry would play a key role in developing and implementing any emissions estimating program. Representing HARC, the author made a proposal to the Board of Directors of the Fire Suppression Systems Association (FSSA) at its February 2001 meeting to endorse and support the development of an HFC Emissions Estimating Program, or HEEP. The FSSA Board support was unanimous and charged the FSSA Technical Committee to take on the project. At its June 2001 meeting the FSSA Technical Committee developed a charge and recruited a Working Group (WG) which met in August to set out the basic structure for the HEEP and identify the follow up tasks and next steps. The WG issued its report in September and was reviewed by HARC at its December 2001 meeting. The progress on the VCOP and the HEEP were reviewed with the EPA in January 2002 [§]. (It is important to note that the EPA's position on the VCOP is one of support and encouragement, not requirement. The operative word in the VCOP is *Voluntary*.) EPA expressed strong support of the progress made by industry and noted that the fire protection industry is the first SNAP sector to advance a VCOP. Suggestions from this meeting led to development of an implementation plan for the HEEP with HARC exercising the role of custodian of the VCOP and HEEP implementation. The VCOP and HEEP progress was reviewed by the author with the FSSA at their February 2002 meeting. While there were a few questions from FSSA members on some implementation details of the HEEP the overwhelming consensus was that the VCOP and the HEEP were necessary and

§ Meeting 23 January 2002. Venue - US EPA offices, 1200 Pennsylvania Ave NW, Washington, DC 20460. Attending - Jeff Cohen, Branch Chief, Alternatives & Emissions Reduction Branch, Global Programs Div., Office of Atmospheric Programs; Bella Marianon, SNAP Program - Fire Suppression; Tom Cortina, Executive Director, HARC; Joseph Senecal, Kidde-Fenwal, Inc.

valuable initiatives in the interests of the industry as a whole.

The *Voluntary Code of Practice For HFC & PFC Fire Protection Agents* and the HFC Emissions Estimating Program were publicly announced at a press briefing at the March 2002 Earth Technology Forum, Washington, D.C.

At this writing several steps remain in the implementation of the HEEP. These include definition of the form of emissions data reporting, communications to identified industry participants, engagement of a confidential Third Party (see below), development of a budget and arrangement for funding.

HFCs and PFCs Used as Fire Extinguishing Agents. The HFC and PFC agents used in fire suppression products are listed in the Table 1. Each agent is identified by its ASHRAE designation. The Global Warming Potential (GWP) is as reported in the 1996 report of the Science Panel of the Intergovernmental Panel on Climate Change [5]. Each agent listed is used in one or more products either singly or in mixtures.

Table 1
HFCs and PFCs Used in Fire Extinguishing Products

Agent	Chemical Structure	GWP 100 yr Time Horizon
HFC-23	CHF_3	11,7000
PFC-14	CF_4	6,500
HFC-125	CHF_2CF_3	2,800
HFC-134a	CH_2FCF_3	1,300
HFC-227ea	CF_3CHFCF_3	2,900
HFC-236fa	$CF_3CH_2CF_3$	6,300
PFC-3-1-10	$CF_3CF_2CF_2CF_3$	7,000

The GWP value of a gas represents its potency as a greenhouse gas relative to an equal amount of carbon dioxide. Thus, emission of 1 kg of HFC-227ea would result in a greenhouse gas effect equivalent to the emission of 3,500 kg of carbon dioxide. In considering the impact of emissions of the fluorocarbon agents the amount emitted must be normalized by multiplying by the GWP value to express the effect in terms of a common reference, namely carbon dioxide.

Definition of "Emission". The goal of the HEEP is to quantify the emissions of fluorocarbon gases from fire extinguishing equipment for reasons other than actually extinguishing a fire, i.e., unintentional emissions, as a basis for measuring industry performance in controlling or reducing such emissions. The recording of an actual emission of agent from equipment at the time it occurs is not a practical way to achieve the goal. There are many owners of equipment and gaining their faithful and consistent cooperation is not feasible. Further, some emissions are not sudden, due to an accidental system discharge, but may be very slow due to a leak in a sealing surface in the product. The structure of the fire equipment industry lends itself to a convenient means of identifying and measuring agent emissions. Virtually all fire extinguishing equipment using fluorocarbon agents is serviced through original equipment distributors of the original manufacturer. The number of such entities is relatively small in North America relative to the number of end users. The end user normally sends the expended agent container to the fire equipment distributor / manufacturer for recharge. Since such action only occurs after an emission of agent we have a simple one-for-one relationship.

Recharge = Emission (1)

This model is not perfect. For example, an owner of a suppression product may, after a discharge, choose to take the product out of service. Such emissions would not be captured by the Recharge = Emissions model. Industry experience suggests that this scenario is not likely to be a frequent occurrence. Other non-report causes may exist. It was the opinion of the HEEP Working Group that the proposed model would capture the vast majority of emissions and was thus an efficacious approach.

Discrimination in Agent Use. The Recharge = Emissions model imposes upon "Reporting Parties", or RPs (see below), the requirement to establish the means to discriminate between agent put into original equipment extinguishers and that used to recharge expended extinguishers. Based on the author's queries with likely RPs this requirement appears to be a low hurdle and in most cases the necessary distinction in agent use is already in place.

Reporting Party. Many businesses are involved in the handling of fluorocarbon agents. But not every such business needs to be an RP. To some extent, the management of the HEEP will be simplified when the number of RPs is as small as possible. Table 2 contains several characterizations of how businesses use agent. Whether or not a business should be an RP depends on whether another business is in a position to report the same agent.

Table 2
Classification of Business by Use of Chemical Agents

Business Type	Business Agent Activity	Reporting Party ?	Reporting Rationale
A	Performs "First Fill only as an original equipment manufacturer (OEM).	No	No associated recharge activity.
B	Performs both First Fill and Recharge. OEMs and "First Fill" distributors.	Yes	Reports recharge quantity.
C	Performs Recharge only. Most authorized distributors.	No	Reported by Type F business that supplies the Type C business
D	Supplies agent to Type A business. Usually agent manufacturer.	No	No associated recharge activity.
E	Supplies agent to Type B business. Agent manufacturer or OEM parent of "First Fill" distributor.	No	Reporting is by the Type B business.
F	Supplies agent to Type C business. Agent manufacturer or distributor's OEM.	Yes	Reports all agent supplied to "C" businesses.

The assessment of business type must be made for each agent type. Some businesses may have different reporting duties for differing agent use profiles.

Example 1. Agent manufacturer supplies two different agents to two different use types.
1. Agent X supplied to Type B OEMs
2. Agent Y supplied to end users who service their own equipment (Type C)

This agent manufacturer would report agent supplied under activity (2) only.

Example 2. A business may fall into more than one category for a single agent. Take the case of the OEM manufacturer who

1. Performs recharge in house;
2. Supplies agent to recharge-only distributors;
3. Supplies agent to "First Fill" distributors.

In this case the OEM would report the agent used in recharge(1) and the agent supplied to the recharge-only distributor (2) but would not report the agent supplied to the "First Fill" distributor (3).

Using this approach the number of Reporting Parties is kept to a small and manageable number. The approach does place some responsibility on agent suppliers and customers to understand the manner in which it is being used and who will report.

Example 3. "First-Fill" distributor of an OEM does mostly recharge and only occasionally "First Fill". In one year this distributor does no "First-Fill". In that year the distributor seems to be a Type C business (Performs Recharge only).
Question: Does this distributor report or not?
Answer: Yes. The determination of business type for reporting purposes must be based on how the business is authorized to work, not how it actually performed in any one year. If the distributor is an authorized "First-Fill" firm then it would report. If the authorization changes (moves from Type B to Type C business) then the reporting duty would change also.

Identification and Accounting of Reportable Agent. Once a business identifies itself as an RP it must then establish the internal processes to identify and account for "reportable agent". While there are several possible approaches to this task the FSSA Working Group took the view that a process most likely to fit into existing business practices was based on use of inventory accounting data that is already normally maintained. These data fall into several categories as follows:

A. Inventory of agent at the beginning of the year;
B. Inventory of agent at the end of the year;
C. Quantities of agent manufactured, purchased, recovered, or otherwise obtained;
D. Agent put into original equipment. This is activity of an original Equipment Manufacturer and its designated and approved "First-Fill" distributors;
E. Agent use to perform recharge of expended extinguisher units;
F. Agent supplied to servicing distributors who perform recharge service only (no First-Fill) on expended extinguisher units; and
G. Quantities of agent used internally, say for product development or other purposes.

Of the above only the agent quantities in categories (A), (B), (C), and (D) need be known. The agent in the other categories, (E), (F) and (G), constitute the reportable agent (used for recharge or otherwise emitted) is determined by difference as follows.

Reportable agent = Beginning inventory + Acquisitions – "First-Fill" – Ending inventory (2)

or

$$E + F + G = A - B + C - D \quad (3)$$

Thus, the RP must be able to distinguish the amounts used for "First-Fill" or other uses. This can be easily accomplished by employing a different part number for agent used in "First-"Fill" from that used in other applications.

Accidental Discharge vs. Fire Suppression Use. The Recharge = Emission model does not discriminate

between agent released accidentally from that used to suppress a fire. The distinction is relevant to the VCOP which has the stated goal of reducing accidental emissions. Naturally it would be preferable to never to have to discharge a fire suppression system of any type for pure reasons of economy. Efforts by the fire protection systems manufacturers to improve early detection technologies may in fact reduce the frequency of suppression related discharge. For the present it would be helpful to the goals of the VCOP if RPs can provide feedback on agent quantities used for recharge where the use is known to have been for suppression of an actual fire. A lament of OEMs, who want to hear of success stories, is that end users are often reluctant to make it known that there was a fire on their premises. Such reluctance may be eased through the use of a confidential third party to whom the RPs will transmit their emissions data.

Reporting. The emissions data collected by the various RPs must be transmitted to the Third Party (see below) for interpretation, amalgamation and reporting to the VCOP Administrator. The form and timing of the reporting is yet to be finalized. To keep the process simple and consistent a single reporting form will likely be used. A draft design of such a form, *Report of Emissions of HFCs and PFCs from Fire Extinguishing Systems / Products,* is contained in Annex A.

Independent Third Party. The HEEP must employ a confidential and independent Third Party for the purposes of receiving, processing and transmitting the emissions data in its final form. Fire industry data relating to agent sales activity in any way is highly confidential to each RP. Thus, confidential treatment of all information supplied by RPs is very important. The independence of the Third Party is essential in order to avoid actual or apparent biases in how emissions data are treated and reported. This point is central to the credibility of the VCOP and HEEP processes.

The primary activities of the Third Party will be to communicate with the various RPs, to receive emissions data, convert the emission quantities for individual agents into equivalent amounts of carbon dioxide, combine the results into a single lumped equivalent carbon dioxide emission, and report that result to the VCOP Administrator (see below). A job specification has been developed by the VCOP Administrator and will serve as the basis for solicitation of proposals from agencies to serve the Third Party Role.

Data Analysis & Reporting by the Third Party. The technical requirements of the Third Party in terms of data collection and analysis are straightforward in principle. Annex B contains a draft Excel worksheet form, *Tabulation of Reported Emissions Data*, for use in logging in data from RPs. This worksheet totals the reported quantities for each agent. Annex C contains a draft Excel worksheet form, *Calculation of Combined Equivalent Carbon Dioxide Emissions*, for use in converting individual agent emissions into equivalent emissions (EE) of carbon dioxide and summing the latter to obtain the combined equivalent emission (CEE) result. EE and CEE are calculated as follows:

$$\text{EE (Agent A)} = \text{Emission (Agent A)} \times \text{GWP (Agent A)} \quad (4)$$

$$\text{CEE} = \text{EE (Agent A)} + \text{EE (Agent B)} + \ldots \text{ for all agents} \quad (5)$$

The math is clearly not difficult. The efforts of the Third Party will likely be taken up primarily in communications with the RPs.

Report to VCOP Administrator. The report of the Third Party could be as simple as a single equivalent emission value for the year of record. In the interests of helping the fire protection industry work toward improving its products and processes it will be useful to have estimates of the portion of all emissions that are due to just cause (fire suppression) or accidental release. The form and constituent details of report from the Third Party to the VCOP administrator are yet to be finalized. Representatives of several likely

RPs will be consulted in developing the final reporting format to maximize consistency and ease of compliance.

Program Administration. The HARC will act as the Administrator of the VCOP and its constituent parts including the HEEP. The roles of Administrator with respect to the HEEP are several including

1. Developing and maintaining the emissions reporting philosophy and methodology
2. Selecting and managing the "Third Party"
3. Developing a reporting schedule
4. Developing an industry communications plan
5. Supervising process and fielding questions from industry
6. Receiving the emissions report from the "Third Party"
7. Reporting the emissions results to the industry & US EPA

HARC, by virtue of its long standing (since 1989) communications links to the key parties in the halon alternatives industry, is well positioned to act as the coordinator and administrator of the details of the VCOP and the HEEP. Several administrative details remain to be finalized. Nonetheless, the HEEP is expected to be launched in the second quarter of 2002 with the goal of making a first report in 2003 of emissions estimates in 2002.

What is the Value of the HEEP? Since the report by Rowland and Molina in 1974 [6] that halogen atoms (chlorine and bromine) in stratosphere destroy ozone, an important absorbing species for solar UV radiation, the attention to the effects of man-made chemicals on the atmosphere has steadily increased. The dialog has evolved from ozone depletion to climate change. The release to the atmosphere of fluorocarbons and sulfurhexafluoride (SF_6)accounts for two to three percent of greenhouse gas loading, while the predominant GHG emissions are due to carbon dioxide, methane and nitrous oxide. The special extinguishing products offered by the fire protection industry which use fluorocarbons are only rarely discharged for fire extinguishing. These products and systems stand largely as insurance against a business disaster due to fire effects. Thus, while the production and sale of equipment employing HFCs and PFCs is a healthy business, the effect with respect to the chemical agents is one largely of increasing an installed inventory of fire suppression chemicals. Due to the infrequency of use for fire suppression and a low rate of accidental release, the use of these products is viewed as essentially non-emissive, a view largely unsubstantiated by data. The HEEP will provide a means to quantify emissions from fire equipment thereby facilitating

1. Substantiation (or not) of emission levels at or below contemporary anecdotal estimates,
2. Establishing an industry benchmark position with respect to emissions,
3. Providing focus for improvement of products and systems leading to reduced emissions for cause or by accident, and
4. Validating the position that the fire protection industry is effectively non-emissive.

Summary. A central operative element of the U.S. fire protection industry's *Voluntary Code of Practice For HFC and PFC Fire Protection Agents* is the duty to coordinate the development of a verifiable data tracking system on the emissions of HFCs across the U.S. fire protection industry. A methodology for such a tracking system, the *HFC Emissions Estimating Program* or HEEP, has been developed through a cooperative industry effort. The method as conceived is simple with respect to identification of reportable emissions and would involve the fewest possible participants thereby simplifying the administration of the program. Key operating aspects of the HEEP have been described including draft examples of documentation for use in reporting, transmitting, and analyzing data. While some final administrative details remain to be fully defined the HEEP, to be administered by HARC, is expected to be launched for

collection of data for the calendar year 2002.

Acknowledgement. Mr. Thomas A. Cortina, Executive Director of HARC, has been a central figure in the development and implementation of the VCOP and the HEEP. I am grateful to Tom for his support on the HEEP and for his very helpful suggestions in the development of this paper.

Abbreviations.

ALT	Atmospheric lifetime
CEE	Combined Equivalent Emission. The sum total of EEs for all agents.
CFC	Chlorofluorocarbon
EE	Equivalent Emission. Emission of an agent as an equivalent emission of carbon dioxide
EPA	Environmental Protection Agency
FSSA	Fire Suppression Systems Association
GHG	Greenhouse gas
GWP	Global warming potential
HARC	Halon Alternatives Research Corporation
HEEP	HFC Emissions Estimating Program
HFC	Hydrofluorocarbon
ODS	Ozone depleting substance
OEM	Original equipment manufacturer
PFC	Perfluorocarbon
SNAP	Significant New Alternatives Policy
VCOP	Voluntary Code of Practice
WG	Working group

References.

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2. English Conference of the Parties Third Session Kyoto, 1-10 December 1997, Kyoto Protocol to the United Nations Framework Convention On Climate Change.
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5. IPCC (!996) *Climate Change 1995: The Science of Climate Change.* Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell, eds., Cambridge University Press, Cambridge, UK. .
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Annex A

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Report on Quantities of HFC and PFC Agents Emitted in Fire Protection Industry Service

Date: mm dd yyyy

To: Name of 3rd Party processing data for VCOP
Address of 3rd Party

From: Name / Address of Reporting Company
Name of Contact Tel (nnn) nnn-nnnn

The information reported herein is proprietary and confidential to the submitter and is supplied to (Name of 3rd Party) voluntarily in support of the product stewardship initiative of the U.S. fire protection industry under the V*oluntary Code of Practice for HFC and PFC Fire Protection Agents* as publicly announced, and endorsed by the U.S. Environmental Protection Agency, March 25, 2002.

Reported herein are amounts of HFC and PFC chemical agents meeting the criteria of "emitted" as defined below.

Definition: "Emitted" chemical refers to a chemical purchased or acquired by the Reporting Party and in turn used, sold or distributed in the marketplace as replacement, or recharge, fire suppression agent for use in fixed or portable fire extinguishing units.

The values reported herein represent the Reporting Party's best estimates of gas quantities used and are the result of a good faith effort to obtain and report accurate information.

Reporting period: 1 January 2002 to 31 December 2002

Quantities of HFCs and PFCs Emitted by Fire Extinguishing Units Indicate Units of Measure ____ lb or ____ kg	
HFC / PFC Chemical ASHRAE Designation	Total Emitted Quantity
HFC-23	
PFC-14	
HFC-125	
HFC-134a	
HFC-227ea	
HFC-236fa	
PFC-3-1-10	

Signed _____ Date _____

Annex B

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Example Hypothetical Data for Illustration Purposes Only

Tabulation of Reported Emissions Data

For each Reporting Party enter the reported emission amount in kilograms.

Emission Data by Reporting Party and Total, kg

Agent Total, kg	1,000	1,500	500	2,000	16,000	2,000	500
Reporting Party	HFC-23	PFC-14	HFC-125	HFC-134a	HFC-227ea	HFC-236fa	PFC-3-1-10
Co. A					5,000	1,500	
Co. B		850					
Co. C	1,000				6,000		
Co. D				2,000			
Co. E			500				
Co. F					4,000		500
Co. H					1,000		
Co. I		650					
Co. J						500	

Example Hypothetical Data for Illustration Purposes Only

Annex C

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Example Hypothetical Data for Illustration Purposes Only

Calculation of Combined Equivalent Carbon Dioxide Emissions

Reporting Year: January – December, 200x

Agent Type	GWP	Total Emission by Agent Type, kg	Equivalent CO2 Emission by Agent Type, 1000s kg
HFC-23	11,700	1,000	11,700
PFC-14	6,500	1,500	9,750
HFC-125	2,800	500	1,400
HFC-134a	1,300	2,000	2,600
HFC-227ea	2,900	16,000	46,400
HFC-236fa	6,300	2,000	12,600
PFC-3-1-10	7.000	500	3,500
		Total	**87,950**

Combined Equivalent Carbon Dioxide Emission of HFCs and PFCs.

87,950 metric tons carbon dioxide

Example Hypothetical Data for Illustration Purposes Only